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SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

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Measurement Techniques

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1960, Number 5 **January, 1961**

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AWARDS FOR THE BEST REFERENCE INSTRUMENT

EXHIBITION OF THE ACHIEVEMENT OF THE USSR NATIONAL ECONOMY

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 1-2, May, 1960

The Committee of the USSR National Economy Achievements Exhibition awarded the Institutes of the Committee of Standards, Measures, and Measuring Instruments with diplomas of the Exhibition of the Achievement of National Economy (EANE-VDNKh) for their success in developing and producing reference measuring instruments, which were exhibited in 1959 in the section of "Metrology, standards, and precision measurements" of the Engineering Pavilion.

A second-grade VDNKh diploma was awarded to the D. I. Mendeleev All-Union Scientific Research Institute of Metrology (VNIIM) for the development of instruments for ac magnetic measurements: instrument UMIPT-1 for measuring toroidal reference ferromagnetic materials magnetized simultaneously by ac and dc fields, and instrument UIMM-2 for measuring reference magnetic materials used at high frequencies (ferrites, ferromagnetic materials, thin rolled sheet materials, etc.).

For the participation in the development of the above instruments, silver and bronze Exhibition medals and valuable presents were awarded to the following members of the Institute: E. T. Chernyshev (leader), E. N. Chechurina, N. G. Chernysheva, Kh. Yu. Fisher, L. S. Levin, and D. I. Malyushin.

This equipment* is intended for use in routine testing (the testing of normal samples used for checking magnetic measuring equipment), for scientific investigation and production control in industry.

This equipment, which has technical characteristics equal to the best modern designs provides measurements of ferrites, thin rolled sheet metal, electrical steels, and nickel alloys at frequencies up to 1,000,000 cps. Such tests lead to the improvement of transformers, computer components, electromagnetic apparatus used in automation, and other electrical components in control and monitoring circuits. The use of these instruments will also considerably improve the quality of radiotechnical and telemetering devices, raise the Q of tuned circuits and devices containing inductances.

A second-grade Exhibition diploma was awarded to the All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Instruments for the development of a reference nonmercury piston type barometer and a portable three-phase installation PTU-2. The designer of the reference barometer, K. I. Khansuvarov, and the designer of the portable installation PTU-2, V. S. Sheiko, were awarded minor silver Exhibition medals and valuable presents.

The reference barometer, which is intended for checking stationary barometers and precision measurements of atmospheric pressure, is portable and makes it possible to check instruments in situ, thus avoiding the transportation of the instruments to be tested.

With respect to its accuracy and stability, this barometer is as good as the best reference instruments. Its weight and overall dimensions are considerably smaller than those of similar instruments (10 kg instead of 100

* A brief description and technical characteristics of the instruments UMIPT-1 and UIMM-2, as well as of PTU-2 and IKP-57 and the reference nonmercury piston barometer are given in Measurement Techniques No. 8, 1959, and the electrodynamic ammeter is described in the same journal No. 1, 1958.

kg); it is compact and easy to operate. The productivity of measurements with this barometer is 3-4 times greater than that with other existing instruments. A great advantage of this instrument is the absence of mercury, which is dangerous to health (in reference mercury barometers, up to 10 kg of mercury is used).

The portable three-phase installation PTU-2, which is intended for checking electricity meters and electrical measuring instruments, differs from the existing installation of the same type by its smaller size and weight, thus making it much easier to use in routine testing.

The checking of instruments in situ by means of this portable equipment has considerably reduced the testing expenditure. In the Moscow region alone, where several hundred thousand electricity meters are in use, the economy will amount to several million rubles due to the saving in transportation.

A second-grade Exhibition diploma has been awarded to the Khar'kov State Institute of Measures and Measuring Instruments for the development and production of an infrared pyrometer IKP-57. The designer of this instrument, V. E. Finkel'shtein, was awarded the major silver medal and valuable presents.

The infrared pyrometer, designed for precision measurements of temperature in the region of 400-1100°C, has a very high sensitivity of the order to 0.5-1°C and is affected but little by the ambient conditions.

The application of this pyrometer for measuring temperatures in hardening metals, controlling their annealing, and other production processes will raise considerably the quality of production. This pyrometer, contrary to the existing models, provides temperature measurements of very small objects (1 × 1 mm), which is required in radiotechnology and in various investigations, and it also makes it possible to measure temperatures of moving objects.

A second-grade Exhibition diploma was awarded to the All-Union Scientific Research Institute of Physiotechnical and Radiotechnical Measurements for developing a reference electrodynamic ammeter ÉDA-3. The designer of the instrument, V. R. Lopan', was awarded a major silver medal and valuable presents.

The reference ammeter ÉDA-3, with a range of 5 to 100 amp, is intended for the calibration of commercial hot-wire ammeters at a high-frequency current in the range of 1 to 100 Mc with an error not exceeding ± 1% for the whole frequency range. The utilization of this instrument provided for the first time the possibility of checking hot-wire ammeters in the above range. The instrument meets the requirements of modern technique and its measuring process has to a considerable extent been made automatic.

This reference ammeter is being successfully used in production for the calibration and checking of hot-wire ammeters and in developing new types of high-frequency ammeters.

LINEAR MEASUREMENTS

A CONTACT INTERFEROMETER WITH AN EXTENDED MEASURING RANGE

V. P. Koronkevich, V. V. Skidan, and V. A. Afanas'eva
Translated from Izmeritel'naya Tekhnika, No. 5, pp. 2-5, May, 1960

For precise comparative measurements of length the following contact interferometers are widely used: types IKPV and IKPG (GOST 8290-57) also known under the PIU code [1], which, within their measuring range (at the most ± 10μ), can be used for absolute measurements of small lengths. One of the methods for extending these limits is described in [2]. For the same purpose the method of optical multiplication of lengths can also be used [3]. Two flat glass plates covered on one side with a layer of silver (reflection coefficient of 80-90%), form the so-called Fabry-Pérot standard, which is the main means for measuring large lengths by the interference method. When white light is transmitted through the standard, some of it will pass through the standard without reflection, and the remaining part will be reflected a varying number of times from the silvered surfaces. All the beams of light which have been reflected an even number of times and the ones which have not been reflected at all will pass through the standard.

If the first standard is followed in the path of the beam by a second which is being compared with the first (Fig. 1) and if the length of the second standard is larger than the first one a whole number of times (for instance, twice as long), the beam which has been reflected in the smaller standard four times, and the one which has been reflected in the larger standard twice, have a zero difference in the length of their paths. If the larger standard is not quite twice as long as the smaller one, this difference will approach zero. With a path difference approaching zero, it is possible to observe fringes in the white light (superposition fringes) and, thus, compare the length of the larger standard with that of the reference standard.

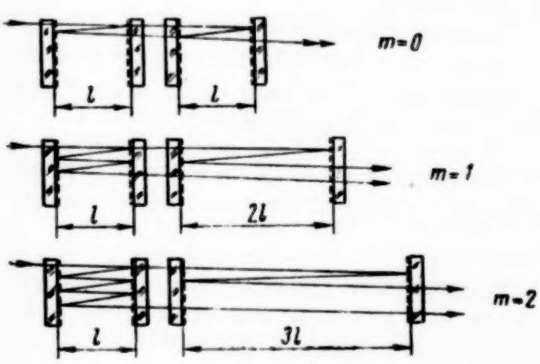

Fig. 1

Taking into consideration that in this system multiple reflections occur only in the first reference standard, the second standard can be replaced by a Michelson interferometer [4]. Thus, a tenfold optical multiplication can be obtained.

For the measurements of small lengths (up to 1-2 mm) we developed on the basis of instrument PIU-1 (we could have utilized on the basis of the same principle instruments PIU-2 or PIU-3) a contact interferometer with an enlarged range [5] based on the method of combining two-beam and multibeam interferometers.

Figure 2 shows the optical schematic and the path of rays in this case. The white light from the incandescent lamp 1 is projected by condenser 2 into the slit of collimater 3. The parallel rays pass from the collimator through filter 4 and the Fabry-Pérot standard 5-6 (of length 1) to the dividing mirror 7 of the Michelson interferometer. If the distance between mirror 9 and the virtual image of mirror 8 is $\underline{n}$ times greater than the length l of the standard, the difference in the paths of the rays reflected $\underline{n}$ times by each of the mirrors in the standard and then separated by mirror 7 and reflected from mirrors 8 and 9 will approach zero. Hence, even in white light interference, fringes of equal width can be observed if mirrors 8 and 9 are not completely perpendicular to each other.

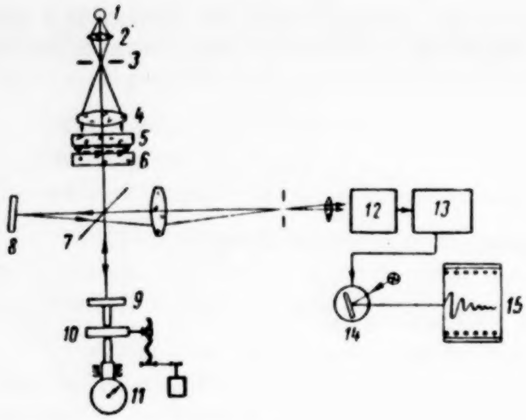

Fig. 2

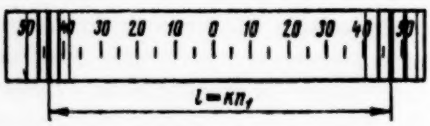

Fig. 3

Thus, by including in the PIU instrument a Fabry-Pérot standard, we are able to observe in white light several systems of interference fringes, which appear whenever the contact tip with mirror 9 is displaced by a distance precisely equal to the distance between the reflecting surfaces 5 and 6 of the standard.

The length of the standard can be determined in terms of wavelengths by means of the coincidence of the fractions of wavelengths method [3] or directly on the PIU instrument by comparison with first-grade end gauges. Moreover, if two interference patterns can be seen simultaneously in the field of vision (Fig. 3), the length of the standard is

$$l = kn_1, \tag{1}$$

where n_1 is the number of scale graduations between the achromatic fringes of two neighboring interference patterns, and k is the scale of calibration.

Thus the measurements amount to determining the order of the interference pattern superposition and the value of displacement of the last black, achromatic fringe:

$$L = lm \pm n_2 k, \tag{2}$$

where l is the length of the standard, m is the order of superposition patterns, k is the value of the scale graduation, and n_2 is the number of the scale graduations by which the last achromatic fringe is displaced.

We tested out several types of Fabry-Pérot standards.

1. Standard consisting of one mica plate silvered on both sides. Such a "solid" standard is very simple to make and does not require any adjustments. The inclusion of such a standard in a double-beam interferometer provides only 2-3 orders of superposed patterns and thus provides only a 4-6-fold extension of the PIU instrument range.

2. Standard consisting of two glass plates separated by an air gap (Fig. 4). Two glass plates 1 and 2 are held in a metal mounting 3. The two glass surfaces which face each other are covered with a reflecting layer of silver. The mica or foil spacers are placed opposite the points of pressure exerted by adjusting screws 4 on the top glass plate. In order to avoid possible additional interference produced by rays reflected from the unsilvered glass surfaces, each glass plate of the standard is made slightly wedge-shaped. The angle of the wedge amounts to some 10'. The adjustment of such standards is very simple and is described in detail in [6].

With a thickness of the standard $l = 10\,\mu$ and a reflection coefficient of the silver layer R = 85-87% we were able to observe 16 orders of superposition patterns, thus extending the range of the contact interferometer 32-fold.

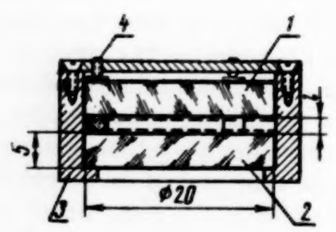

Fig. 4

An extended range contact interferometer was used at the D. I. Mendeleev All-Union Scientific Research Institute of Metrology for measuring magnetostriction [7], checking screws of optical micrometers, and for precise measurements of angles of small wedges.

Below we examine by way of an example the possibility of using an interferometer for checking micron and micron-fraction indicators; in the latter case the range of the PIU instruments was extended 100-fold.

For this purpose standards 100μ long were made. The length of the standards was determined directly on the PIU instrument by means of two first-grade block gauges, whose difference in length amounted to 500μ. In a consecutive setting of these gauges on the instrument, the contact tip of the interferometer was displaced by 500μ, and the field of vision was traversed by five orders of fringe patterns ($m = 5$). The length of the standard was calculated from (2). The bracket which carried the indicator 11 under test (Fig. 2) was mounted directly on the interferometer stand. The quartz block gauge 10 was rigidly connected to the table of the PIU instrument. The displacement by means of a microscrew of the instrument table (and hence, of the quartz gauge) conveyed a similar displacement both to the interferometer tip and the measuring rod of the indicator. The parallelism of the gauge displacement was controlled by means of an autocollimator.

By displacing the indicator in steps of 100μ, it was possible to count in the interferometer field of vision displacements of the black, achromatic fringe. These displacements are proportional to the error of the instrument under test.

The visual method of observations was replaced by us with a photoelectric method of registration in the same manner as it was done in [8].

For this purpose the interferometer was connected to a photoelectric receiver 12 (Fig. 2) followed by an amplifier 13 whose output was connected to a galvanometer 14. The light beam from the mirror galvanometer was projected onto a revolving drum 15 with a photosensitive paper.

The interference pattern thus obtained (Fig. 5) clearly shows the zero fringe and, hence, the exact instant when the contact tip passes a distance equal to the Fabry-Pérot standard.

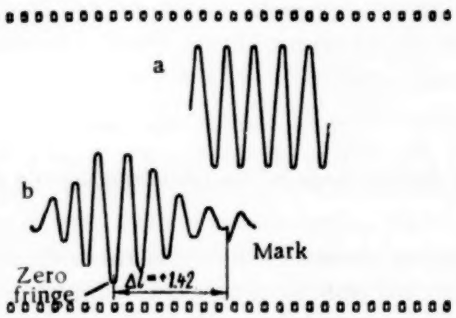

Fig. 5. a) fringes in a monochromatic light, $\lambda = 0.557\mu$; b) fringes in a white light, Δl is the indicator error.

By means of an instantaneous shorting of the galvanometer 14 input a mark is made on the film at the instant the indicator reads zero. Thus, the error of the indicator reading is expressed by the distance of the zero fringe to the mark. In order to be able to determine the error directly in terms of wavelengths, interference fringes of some monochromatic source are also recorded on the same film. The recording of the interference patterns in white light is carried out from the zero to the fifth order. The contrast of the higher-order patterns is considerably lower than that of the zero and first orders, but the achromatic fringe can still be clearly distinguished.

In order to raise the accuracy of recording the mark, the position of the indicator pointer was observed through a microscope.

A comparison of measurements made by means of the photoelectric method and those made by checking against block gauges, carried out with an indicator model, showed an agreement within the expected limits of accuracy.

On the basis of these tests it was possible to determine the advantages and defects of this method of determining the errors of indicators. The advantages include the objectivity and reliability of the results and the possibility of determining the error of the reversed direction of measurement of the indicator.

The error of micron indicators amounts to several microns, which corresponds to a considerable distance between the mark and the zero fringe on the diagram (15-20 fringes). This in turn increases the time taken up by checking and decreases its accuracy. Hence, the contact interferometer with an extended range should be recommended for the checking of more accurate instruments.

A contact interferometer without the photoelectric circuit can be easily made in any laboratory which possesses standard interferometers of the type of PIU-1, PIU-2, or PIU-3. For this purpose it is only necessary to change the construction of the illuminator in instrument PIU-1 as shown in Fig. 2. In the type PIU-2 and PIU-3 instruments, the Fabry-Pérot standard can be placed between the condenser and the filter. In order to increase the contrast of the fringes, the light to the standard should be passed through a diaphragm with an opening 1-2 mm in diameter.

SUMMARY

The experimental work carried out makes it possible to conclude that the extended range interferometer can be widely used for accurate measurements of small lengths. The interferometer can be easily adapted for checking microcators, opticators, ultraoptimeters, strain-gauge calibrators, optical micrometer screws, angles of small wedges, for measuring magnetostriction, determining the linear temperature expansion coefficients, and other purposes.

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AN ATTACHMENT FOR MECHANIZING LINEAR MEASUREMENTS

N. G. Basin
Translated from Izmeritel'naya Tekhnika, No. 5, pp. 5-7, May, 1960

Below we describe samples of assembled universal checking devices made by the Interchangeability Bureau for such typical details as shafts and rings.

These devices consist of a set of standardized units for measuring diameters and lengths and for the setting of objects and fixing of all apparatus on a common base. The quantity and position of units are determined by the construction and the parameters of the controlled objects. Checking is conducted visually by means of indicating instruments, or electrical contact transducers with illuminated displays. Calibration can be done with two reference details, made for upper and lower tolerances, or with one reference detail and indicators or settings of transducers, or, finally, with one certified detail found at random and settings of indicators or transducers.

The device for checking smooth and stepped shafts with diameters up to 110, and lengths up to 800 mm, can control diameters of all the shaft necks with an error not exceeding $\pm 2\mu$ and the lengths of the shafts, necks, and steps with an error not exceeding $\pm 15\mu$, the relative positions of the surfaces, end and radial wobble, and errors of shape such as deviations from a circular or cylindrical form.

The measuring device for diameters (Fig. 1) consists of a caliper gauge with two jaws 1 which can be displaced along pipe 2, and so adjusted to the required diameter size. The floating tip 3, suspended from one of the jaws on flat springs 4, rests with one end on the detail and with the other on an indicator or transducer 5. The introduction of this intermediate component frees the measuring rod of the indicator from radial stresses when measuring the detail. The caliper gauges are made to float on flat suspension springs.

When the rigid jaw is separated from the detail, and the instrument is thus converted from a double- to a single-contact measuring device, it becomes possible to measure the radial wobble of any required neck with respect to the neck journals. The detail is rotated manually, but a mechanized drive can be supplied if required.

* See English translation.

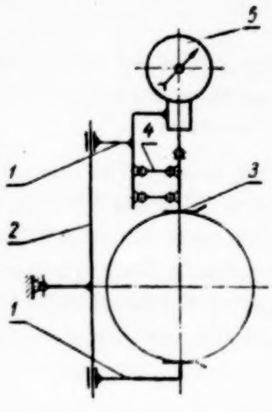

Fig. 1

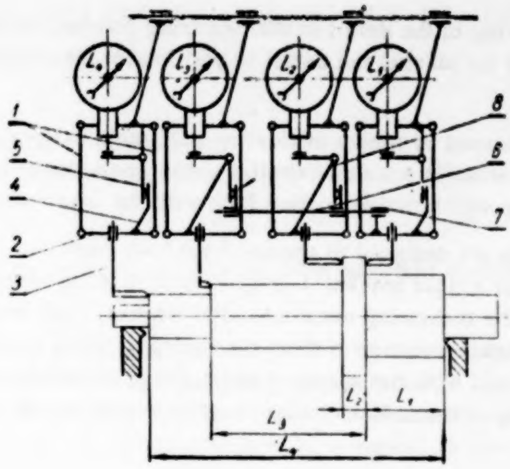

Fig. 2

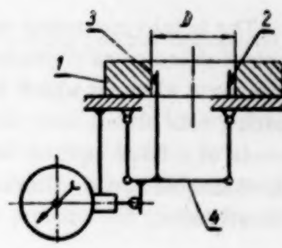

Fig. 3

The problem of measuring lengths is made more complicated by the fact that dimensions on details are not always taken from a single base; hence, when it is desired to check all the dimensions simultaneously, it is necessary to introduce in addition to the fixed base other, floating bases as well. This problem is solved in the following manner: the butt of the detail to which most of the measurements are referred is taken as the base, and this butt is pressed against the fixed support. In this instance the measuring device consists of a junction parallelogram made up of flat springs 1 (Fig. 2) and rigid strips, to one of which measuring tip 3 is rigidly connected with the other carrying the indicator. Strip 2, to which the tip is fixed, also carries a rigid heel 4 making contact with an angle lever 5, whose end is connected to the indicator. Thus, the indicator shows the position of the strip and tip with respect to the butt of the detail.

If it is necessary to measure from a floating base, the strip with the tip is fixed to an extended plunger 6 which is fixed to heel 7 making contact with lever 8 of the measuring device designed to measure from the floating base. In this instance, contrary to the previous arrangement, the angle lever is fixed to the strip of the measuring tip instead of the indicator strip. The reading of the indicator is now determined both by the position of the strip to which the lever is fixed and of the strip in contact with the plunger coming from the preceding measuring device, i.e., by the relative positions of the corresponding butts of the detail.

The measuring device for determining positions from a rigid base can also serve to measure end wobble. In this instance the butt rest must be fixed to the butt whose wobble it is desired to measure, and the tip of the measuring device should be held against the diametrically opposite point of the detail. A rotation of the detail through 360° gives double the value of the end wobble. The details are pressed against the rest through flat springs of the measuring device in a manner similar to the one used in the case of measurements of length.

The details are fixed in the measuring device on knife-edge bearings, thus reducing to the minimum the time required for fixing and taking off details. The knife-edge bearings and the cross section under test are placed at an angle of 20° to the vertical, thus making the reading of the indicator and placing of the detail convenient, and providing a stable position for the detail. The knife-edge bearings provide a base for the details both in the axial and radial directions. In order to make the adjustments easier, the knife-edge bearings have a scale by means of which the back square is set to the required size of the journal neck. One of the knife-edge bearings includes a lever and a microswitch which connects the current only when the detail is placed in the measuring position. In the axial direction the knife-edge bearings move along a plate and are secured in the required positions which correspond to the journals of the detail.

The device for checking rings is designed for two standard sizes of details up to 100 mm in diameter and those between 100 and 250 mm in diameter. The device provides the checking of external and hole diameters with an error not exceeding $\pm 2\mu$, and of the depth of all steps with an error not exceeding $\pm 5\mu$.

The detail is based by its hole and lower butt end. The opening of the detail 1 (Fig. 3) is placed on three pins set to the required diameter. One of the pins 2 serves as a fixed rest from which the measurement of the internal diameter of the detail is made by means of the double contact system; the second pin 3 is made to float on flat springs connected to strip 4 which has a heel contacting an indicator.

In order to facilitate the placing of the detail in the measuring position, the setting pins are mounted on a ball-bearing carriage, which is used for placing the detail in position for measuring its external diameter and height.

The external diameter is measured by means of floating adjustable caliper gauges, whose two jaws can be displaced along knife-edge guide rails. In a manner similar to the one adopted for measuring shaft diameters, one of the jaws carries a guiding tip which makes contact both with the detail and the indicator.

The height-measuring devices are designed to operate from both fixed and floating bases. The first type consists of an indicator suspended from a rigid bracket 1 (Fig. 4) and making contact with the detail through an intermediate element which frees the measuring rod from radial stresses. The device for measuring heights from a floating base differs from the foregoing arrangement by the indicator being suspended from a floating bracket 2 instead of a fixed one, by being held with flat springs 3, and referred to the second butt of the detail by means of an adjustable rest 4. The reading of the indicator thus becomes dependent on the relative position of two of the detail butts.

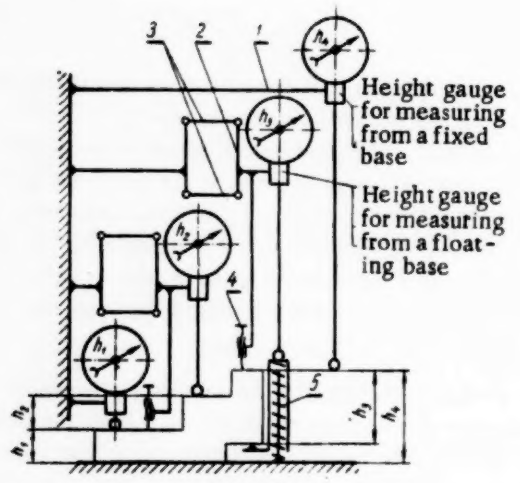

Fig. 4

Both measuring devices are set for a height and a radius of the detail, and the device measuring heights from a floating base is also provided with the possibility of a relative displacement of the tip in contact with the two butts of the detail.

When it is required to measure a height from an internal lower butt, to which it is not convenient to refer other measurements (for instance, from a web of a gear wheel), a special floating base consisting of a floating sprung plunger 5, which contacts with its lower end the butt of the detail and with its upper end the tip of the measuring device, is used. The second tip of this device rests against the second butt of the detail.

The device for measuring heights can be fixed either on a rigid plate or on a floating carriage.

SUMMARY

The optimum method of mechanizing production measurements of dimensional parameters in engineering, especially under conditions of small-scale mass production in small establishments, consists in the use of universal checking devices which comprise a set of independent compound units, whose production must be undertaken by our instrument-making industry. This solution of the problem frees the customer plants from the necessity of producing special equipment, since they will only have to choose the measuring arrangement and a set of units whose various combinations can be used for checking details of any given type. This method will raise the quality of the control gear and lower its cost, will reduce to a minimum the time required for its assembly and familiarization with its measurement techniques; it will simplify the organization of inspection and speed the measuring.

AN AUTOMATIC METHOD OF ENSURING ACCURACY OF DIMENSIONS IN CENTERLESS GRINDING

S. S. Volosov and G. B. Turbin
Translated from Izmeritel'nayaTekhnika, No. 5, pp. 7-9, May, 1960

Automation of the active (regulating) control is the most efficient method of making control operations automatic.

Self-adjusting systems are one of the most prevalent forms of active automatic control. It is known that one of the distinguishing characteristics of a self-adjusting system is that it compensates only for functional errors in technological processes and does not eliminate the effect of natural random errors. The evaluation of the error dispersion parameters in technological processes is, therefore, a necessary prerequisite to the development of any self-adjusting system.

The most perfect systems are those based on self-adjustment to a mean value, including adjustment to mean or median sampling values. When self-adjustment is made to mean values, the instrument responds to random variations of the details to a considerably smaller extent than for adjustments made to a single detail.

It is known that the rms deviation of the arithmetic mean value is

$$\sigma_{\bar{x}}=\frac{\sigma}{\sqrt{n}},$$

where n is the number of sampled details.

In determining the value of the median, the rms error amounts, for a normal distribution law to

$$\sigma_m=\sqrt{\frac{\pi}{2}}\cdot\frac{\sigma}{\sqrt{n}}$$

Hence, when adjustment is made with respect to the median, the effect of random errors is eliminated to a smaller extent than when the mean value is taken as a basis. This, however, can be easily compensated by increasing the number of sampled details. On the other hand, the adjustment to the median has considerable advantages as compared with the adjustment to a mean value consisting in the much smaller effect on the measurement results of large errors in the technological process or in the actual measurements, such as burrs, adhering filings, etc.

Adjustment to the mean value is especially beneficial when control is exercised by means of short pulses which would lead to an increased production error if adjustments were made with respect to a single detail.

Experiments have shown that the accuracy of the self-adjusting systems depends but little on the accuracy of the transducer. It depends to a far greater extent on the quality of the articles under test, the rigidity of the equipment, sensitivity of the actuating mechanism, etc.; i.e., on purely technological factors. Hence, before self-adjusting systems are adopted in production, the production process itself must be first set in order. It is precisely owing to the low quality of technological processes that self-adjusting systems cannot be introduced in many plants at the present time.

Since the self-adjusting system does not compensate for the effect of natural random errors of production, it is necessary before starting any development of the instrument to determine the size of the dispersion zone of the natural random production errors, and separate the latter from the random functional errors. For this purpose either the group or the difference methods can be used.

Below, we examine the problem of developing a self-adjusting device for controlling a centerless grinding machine for conical roller bearings. Before the instrument was developed, we analyzed the accuracy of the existing grinding process. Figure 1 shows the variations in the diameters of three consignments of roller bearings

ground at different times on different days. It will be seen from the graph that, ignoring the large errors of machining, which lead to sharp negative deviations in size of roller diameters, it is possible to use in this instance a self-adjusting system for grinding roller bearings (the field of the natural random error dispersion in machining comes well within the tolerance field).

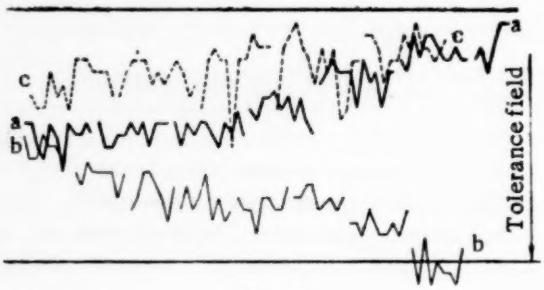

Fig. 1

An analysis of random deviations shows that their distribution approaches the normal law. Curves a and c display a tendency for a gradual rise in roller diameters with time, which is due to the wear of the grinding wheel. The gradual decrease in the size of the roller diameters in curve b is due to this consignment having been ground at the beginning of a shift, when the effects of the temperature deformation of the equipment are larger than those caused by the wear of the grinding wheel. It will be seen from the curves that the variations in the roller diameters are very gradual, thus making it possible to omit checking all the rollers produced on the machine. This circumstance greatly facilitates the designing of the measuring device, if one takes into account that the rate of operation of the machine is very high (50-90 rollers per minute).

Curve c indicates large machining errors in the centerless grinding of rollers, whose diameters have sharp negative deviations. These deviations are due mostly to the small sizes of the rollers fed to the machine and errors in machining of their butt ends.

These large machining errors made us select a self-adjusting device with respect to the median. It should also be noted that an instrument designed on the basis of self-adjustment with respect to the median is considerably simpler than the one using the mean sampling value as a reference.

Self-adjustment by means of the averaging method is also required because the control is carried out by means of short pulses.

Self-adjustment is achieved by a consecutive control of six sample details. The design of the measuring equipment is based on that of the measuring device of the automatic machine for sorting tapered roller bearings. Measurements are made by means of a hard alloy ring into which the rollers are pushed with a push rod 1 (Fig. 2). The position of the push rod is determined by the size of the roller under test. The rod is connected to transducer 2 whose contact 3 is either open or closed, depending on the diameter of the roller.

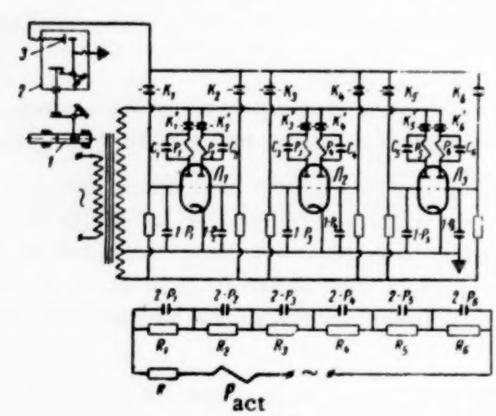

Fig. 2

The electrical circuit of the device which provides self-adjustment with respect to the median consists of three double triodes T_1, T_2, and T_3. At the beginning of measurements all the tubes are blocked. During measurement contacts K_1, K_2, K_3, K_4, K_5, and K_6 are closed in turn by means of a special distributor, thus making the current pass through each half of a triode in turn. If the transducer contact is open, the tubes remain locked. If the contact is closed, the corresponding half of the tube remains conducting and operates one of the relays P_1, P_2, P_3, P_4, P_5, or P_6. The operated relay closes contact $1\text{-}P_1$ or $1\text{-}P_2$, etc., thus locking the corresponding relay. At the same time contacts $2\text{-}P_1$ or $2\text{-}P_2$, etc., are closed and the corresponding resistors R_1, or R_2, etc., are shorted in the actuating relay P_{act} circuit. This relay will operate when three resistors are shorted. At this instant the median is equal to the standard for which the transducer has been set. When the seventh detail arrives at the measuring position, the distributor disconnects the relay P_1 circuit by opening contact K'_1 and thus preparing the left side of tube T_1 for the measurement of the seventh detail. Then the eighth, ninth, etc., details (i.e., details two, three, etc., of the second series) are measured in a similar manner. Since the median is measured by consecutive checking of details which comprise the sampling, in essence the instrument checks the current (sliding) value of the domain.

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AN INSTRUMENT FOR CONTROLLING WAVINESS AND DEVIATIONS FROM THE CORRECT GEOMETRICAL SHAPE

T. S. Lopovok

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 9-10, May, 1960

The Moscow Machine-Tool Institute in conjunction with the Interchangeability Bureau produced an instrument for checking the waviness and shape of cylindrical details 70 to 700 mm long and 10 to 70 mm in diameter.

The instrument provides measurements of longitudinal and transverse waviness as well as deviations from the correct cylindrical shape, such as a tendency to become oval, polyhedral, tapered, etc. It is also possible to determine by means of the instrument complex deviations along the axis of the cylinder, such as the runout of one shoulder with respect to another, difference in diameters, etc. For the evaluation of the tested dimensions, a micron indicator is included in the instrument. Wave diagrams in rectangular coordinates are obtained by means of a recording inductive device BV-662 and a miniature transducer BV-908. Recording can be combined with visual observation on a pointer instrument.

Measurements can be made manually or by means of a motor drive.

When a motor is used, the time of the revolution of a detail amounts to 86 sec, the speed of displacement of the measuring carriage along the axis of the detail to 10 mm/min, and speed of the paper which records the profilograms amounts to 200 mm/min. Thus, the linear speed of probing the detail along its circumference or helically can vary from 3.66 to 25.6 mm/min, depending on the diameter of the detail under test, and the linear speed of probing along the axis is constant and equal to 10 mm/min. Moreover, even at a maximum speed of probing, irregularities with a pitch of 0.1-0.07 mm and a height of the order of 0.2-5μ are recorded, since the inductive recorder BV-662 can operate at the rate of 5-7 displacements of the transducer tip per second with an amplitude of 2-5 mm (on the paper chart). Thus, surface waviness even with the smallest-size waves, which do not exceed 1 mm in pitch and 0.5-1μ in height can be recorded comfortably by the instrument.

For investigation purposes the instrument is supplied with a set of measuring tips with varying radii of curvature between 0.1 and 250 mm. The measuring effort can be controlled in the range of 50 to 400 g-wt.

Figure 1 shows the schematic of the instrument (A is the headstock, B the tailstock and C the measuring carriage).

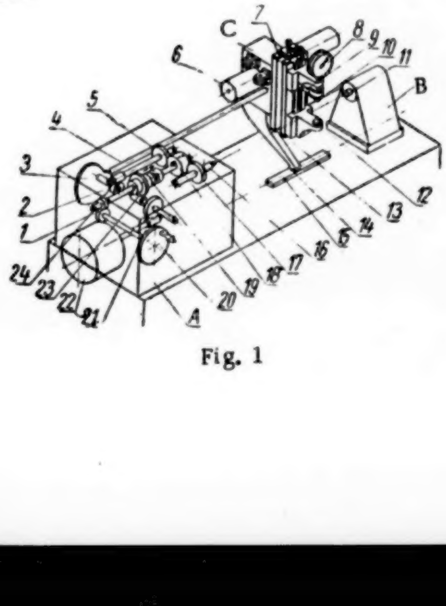

Fig. 1

The detail under test is placed between the centers 11 and 16. The surface of the detail is probed by two tips 10 and 12 simultaneously (when the diameter is measured), or by top tip 10 only (when the radius is measured). The measurements of the diameter or the radius are read off indicator 8. When diameters are being measured, springs 7 and 13, which support the measuring part of the carriage, are free; the measuring device operates as a caliper gauge. When the radii are being checked, springs 7 and 13 are fixed, and only the displacements of the top tip 10, which is suspended on

flat springs 9, are being measured. Carriage C moves along cylinder 6 and can be rigidly connected to drive 4, which rests with its end on cam 3. When radii along the longitudinal section are measured, guide rail 15, which carries heel 14 and supports the entire measuring carriage, serves as a basis for these measurements.

When the device is operated manually, the rotation is transmitted from flywheel 20 to shaft 24 through worm gear 1.

When the device is operated from motor 22, the rotation is transmitted through worm gears 21 and 23 to the same shaft 24. When clutch 19 is moved to the extreme left position, gear 18 is free to rotate and move along the cotter pin to three positions. In the middle position shown in the drawing, gear 18 engages simultaneously with gears 17 and 5. In this position gear 17 drives the detail through the collar and carrier, and gear 5 displaces the measuring carriage through worm gear 2 and cam 3. In combining these two movements, it becomes possible to test the detail along a helical line. In the extreme right position of gear 18, gear 17 disengages, and only the measuring carriage is displaced, i.e., the irregularities in the cross section along the axis of the detail under test can be investigated.

For recording wave diagrams an inductive transducer BV-662 can be plugged into the output socket of the device instead of the indicating instrument. Since the transducer has a special plug-in arrangement for an indicating instrument, it is possible to obtain a simultaneous visual indication.

Figures 2 and 3 show samples of the wave diagrams obtained on this instrument with a vertical magnification of 5000. The recording was made of two cross sections of a grinding machine spindle 50 mm in diameter. The measuring tip used had a radius of curvature of 15 mm.

Fig. 2

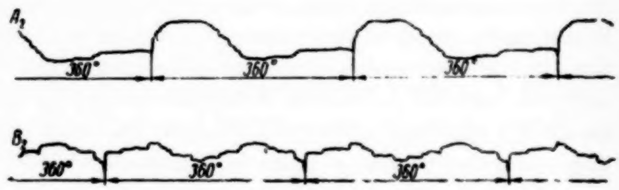

Fig. 3

The top two wave diagrams A_1 and A_2 represent the variations of the radii, and the bottom two B_1 and B_2, those of the diameters in the same cross sections. The diagrams display a good consistency.

Preliminary investigations have shown that the instrument is highly accurate and stable. Its limiting measuring error should amount to 1-1.5μ.

The instrument has four steps of vertical magnification: 500, 1000, 2000 and 5000; its horizontal magnification varies in the range of $\sim$1.15 (for diameters of $\sim$70 mm) and $\sim$8 (for small diameters of $\sim$10 mm). The time taken to record a wave diagram of one revolution of the detail is 1.25 min, irrespective of the detail diameter; along a helix it is 6.25 min for 5 turns, and along the axis of the detail, it is 5 min for a length of 50 mm.

The range of the measured irregularities amounts to $HB_{min} = 0.2\mu$ and $HB_{max} = 400\,\mu$.

The instrument can be recommended for investigating the microgeometry of such accurate devices as plungers, lathe spindles, etc.

DETERMINING THE WAVINESS OF RACEWAY SURFACES IN FRICTIONLESS BEARING RACES

B. E. Bolotov
Translated from Izmeritel'naya Tekhnika, No. 5, pp. 10-11, May, 1960

When the effect of geometrical errors on the noise and vibration of bearings is studied, it becomes necessary to determine several parameters of the races: their tendency to be oval, polyhedral, wavy, or rough. The polyhedral tendency and waviness of the surface of bearing races which work at the most common speeds produce a marked effect on the generation of noise, since these defects provide the highest radial acceleration of rolling bodies. In order to be able to calculate the radial acceleration, it is necessary to know the length and shape of the wave and its height, or else have a wave diagram of the race surface.

The IV-1 instrument described below provides, in practice, a measurement of the height of waves in the range of 0.05 to 1μ. Depending on the initial gap between the plates of the transducer, this range can be extended to 20μ.

This device is based on the measurement of small displacements by means of a capacitative transducer (Fig. 1). The race 1 under test is fitted onto mandrel 2 which is fixed in centers 3 and is rotated by a motor through a light belt drive and a reduction gear, all of them mounted in the body of the instrument. Lever 4 can rotate in the vertical plane of bearings 5. The lever carries a measuring probe 6 and the top plate of the capacitative transducer 7. For the purpose of calibrating the transducer and setting the working gap δ between plates 7 and 8, the latter can be displaced vertically by means of a micrometer screw 9. A decrease in the working gap δ of the transducer increases its sensitivity. The transducer is connected to the input of an electronic amplifier 10 [1].

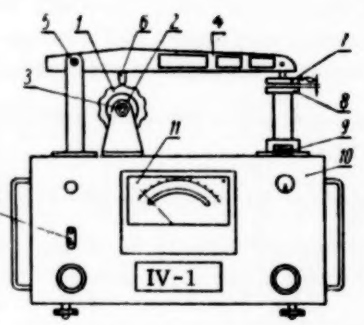

Fig. 1

Fig. 2. Wave diagrams of the race surfaces. a) wave diagram of the bearing raceway taken after grinding, b) ditto, after polishing.

The maximum height of waves in microns can be read off the microammeter 11 scale. For recording the wave diagrams, a loop oscilloscope type MPO-2 is used when it is plugged into socket 12.

The measuring effort of the instrument amounts to 5 g-wt. In order to ensure a constant contact of the measuring probe with the race, the latter is rotated at a small peripheral velocity (4-5 cm/min). The radius of curvature of the measuring tip was made equal to 2 mm, thus making it possible to record wavelengths of not less than 0.2 mm.

By varying the extension of the contacting probe and the diameter of the mandrel, it is possible to check races from 15 to 30 mm in diameter.

The error of the instrument over the whole of the measuring range amounts to ± 5%. The over-all dimensions of the wave recorder are 250 × 180 × 160 mm, and its weights is 5 kg.

Figure 2 shows wave diagrams of the race surface of bearing 204. The raceway of this bearing has a waviness with a pitch of 0.2-1.0 mm and a maximum wave height of 3 μ.

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THE EFFECT OF MANDREL ECCENTRICITY ON THE ACCURACY OF EDGE CAMS

A. V. Rumyantsev

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 11-14, May, 1960

Mathematical functions of a single variable, representing movements of various elements of a mechanism, etc., are often simulated by different edge cams whose accuracy is determined by the machining errors of their working surface or the error in their radius vector ΔR.

The eccentricity of the mandrel Δl, both in the machining and measurement of the cam working surface, produces a displacement in the surface with respect to the geometrical axis of the seating hole and an error in the radius vector equal to $\Delta R_{\Delta l}$.

Distance OO_1 (Fig. 1) between center O_1 of the seating hole and center O of the mandrel represents length Δl of the eccentricity vector, and Θ, its angle with respect to the initial (zero) position of the cam.

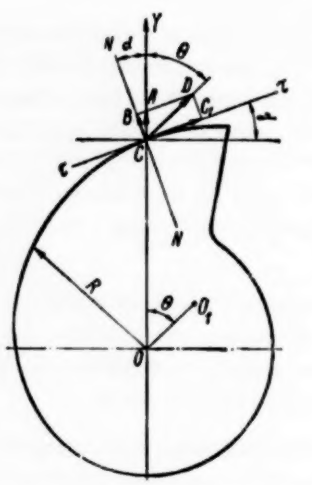

Fig. 1

In order to determine the error in the radius vector $\Delta R_{\Delta l}$, let us displace the eccentricity along the axis OY from point O to C–the point of contact of the instrument with the working surface–without rotating the cam, and let us preserve its direction at the angle Θ. Then let us project the eccentricity vector onto normal NN to the working surface at point C and onto the tangent $\tau\tau$ to the curve at the same point.

It is obvious that only the projection BC to the normal will produce an error in the radius vector, and that projection CC_1 onto the tangent will only cause a slip of the cam with respect to the tool in machining and with respect to the probe in measurements.

Then the eccentricity vector projection onto the normal will be

$$BC = DC\cos(\Theta+\alpha) = \Delta l\cos(\Theta+\alpha),$$

where α is the angle between the normal NN and axis OY, the elevation angle of the working surface.

The radius-vector error in this case is determined by the value of $CA = \Delta R_{\Delta l}$.

From triangle ABC we shall obtain the radius-vector error due to eccentricity Δl:

$$CA = \frac{BC}{\cos\alpha}$$

and

$$\Delta R_{\Delta l} = \frac{1}{\cos\alpha}\cos(\Theta+\alpha)\,\Delta l. \tag{1}$$

Equation (1) accounts for the error $\Delta R_{\Delta l}$ in the initial position of the cam, when the eccentricity with respect to the initial radius vector is at an angle Θ. When the cam is rotated through angle φ from its initial position [(1)], this angle must be accounted for, and then the radius-vector error in any position of the cam will be determined by the equation

$$\Delta R_{\Delta l} = \pm\frac{1}{\cos\alpha}\cos(\Theta+\varphi+\alpha)\,\Delta l. \tag{2}$$

When the eccentricity OO_1 in the first or second quarter of the circle, the working surface of the cam is raised by $\Delta R_{\Delta l}$, and, in machining, reduced by that value. When the eccentricity is in the third or fourth quarters, however, the working surface will be lowered with respect to the cutting tool by $\Delta R_{\Delta l}$ and the radius vector is increased by that value both in machining and in measurements.

The error $\Delta R_{\Delta l}$ will be largest when $\cos(\Theta + \varphi + \alpha) = 1$, i.e., when

$$(\Delta R_{\Delta l})_{max} = \frac{1}{\cos\alpha}\Delta l. \tag{3}$$

The maximum error in the radius vector with an angle of elevation of the working surface of $\alpha = 30°$ will be $1.15\Delta l$, with $\alpha = 45°$ it will be $1.43\Delta l$ and with $\alpha = 60°$ it will be $2\Delta l$.

The modulus of eccentricity Δl, both of a single sample and a batch of cams, is a constant, since the working surface of a batch of cams is machined and measured on a single mandrel with a constant radial wobble. Depending on the accuracy of the cams, the mandrel is made in various plants with a radial wobble of 4 to 15μ. The machining and measurement of accurate cams is done on mandrels with a radial wobble of 4-6μ. With a wobble of 6μ the eccentricity is $\Delta l = 3\mu$.

In the final analysis, then, calculation of the error will be based on $\Delta l = 3\mu$.

Angle Θ can be measured for a single sample, but for a batch of cams it can be either a constant, when the cam blanks are fixed on the mandrel in a definite position with respect to the initial or zero position, or it can have a random value, when the blank is fixed on the mandrel in an undetermined position.

In the first instance, both for batches of cams and single samples, error $\Delta R_{\Delta l}$ is determined from (2), in which angle φ is known, angle Θ is measured by means of the indicator, $\Delta l = 3\mu$, and α is either known or it can be determined from the machining tables by means of the formula

$$\mathrm{tg}\,\alpha = \frac{R_1 - R_2}{R_2\varphi}. \tag{4}$$

The values of R_1 and R_2 are taken from machining tables for the corresponding points of the working surface [1].

Figure 2 shows a graph of error $\Delta R_{\Delta l}$ plotted from (2) for $\Delta l = 3\mu$, by means of which it is possible to find quickly and easily the error $\Delta R_{\Delta l}$ for any point of the cam working surface with various angles of elevation.

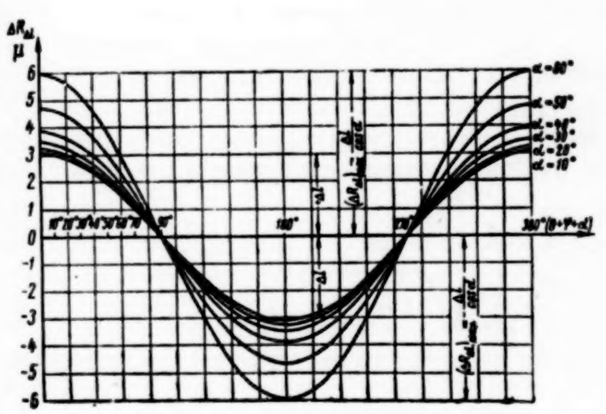

Fig. 2

In the second instance, when Θ is a random quantity, the error $\Delta R_{\Delta l}$ also becomes a random quantity, whose distribution can be determined by the laws of the theory of probability.

Let us determine the law of distribution of the random quantity $\Delta R_{\Delta l}$ and find its probability characteristics: its mean value $M(\Delta R_{\Delta l})$ and its rms value $\sigma(\Delta R_{\Delta l})$.

For the sake of convenience let us denote the constant part of (2) by $a = \Delta l/\cos\alpha$ and angle $\omega = \Theta + \varphi + \alpha$.

Then (2) will assume the following form:

$$\Delta R_{\Delta l} = a\cos\omega \tag{5}$$

whence

$$\omega = \cos^{-1}\Delta R_{\Delta l}. \tag{6}$$

Angle ω has a uniform differential distribution law

$$p(\omega) = \frac{1}{2\pi}$$

in the interval

$$0 \le \omega \le 2\pi.$$

The differential distribution law of the error $\Delta R_{\Delta l}$ is expressed by the formula

$$p(\Delta R_{\Delta l}) = \frac{\cos\alpha}{\pi\Delta l}\frac{1}{\sqrt{1-\left(\frac{\cos\alpha}{\Delta l}\Delta R_{\Delta l}\right)^2}} \tag{7}$$

Figure 3 shows the differential distribution law of $p(\Delta R_{\Delta l})$ in the form of a graph for various values of the angle of elevation α.

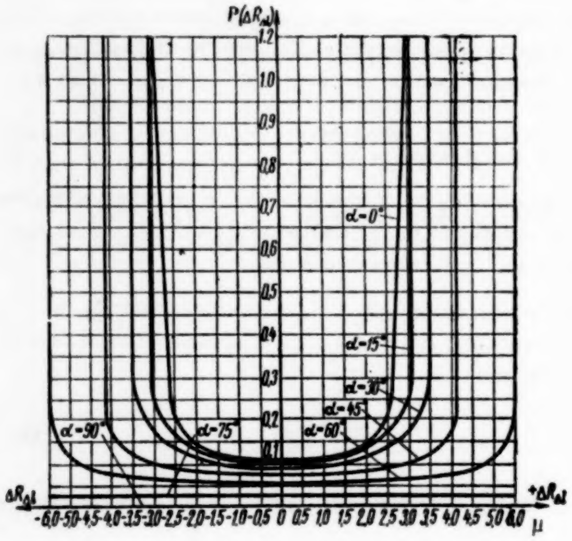

Fig. 3

It will be seen from (7) that when $\Delta R_{\Delta l}$ is tending to $a = \Delta l / \cos\alpha$ the expression under the sign of the radical in the same formula is tending to zero. Hence, the density $p(\Delta R_{\Delta l})$ will tend to infinity. Moreover, $p[(\Delta R_{\Delta l})_{max}] = \infty$, for $\alpha = 0$ when $(\Delta R_{\Delta l})_{max} = 3\mu$, for $\alpha = 45°$ when $(\Delta R_{\Delta l})_{max} = 4.2\mu$ and for $\alpha = 90°$ when $(\Delta R_{\Delta l})_{max} = \infty$.

In order to determine the value of $\Delta R_{\Delta l}$, which is a random quantity, it is necessary to find the distribution law for $p(\Delta R_{\Delta l})$, from which it will become clear how often and with what probability $\Delta R_{\Delta l}$ assumes various values.

The curves in Fig. 3 show that the values of the random quantity further removed from $\Delta R_{\Delta l} = 0$ occur with greater frequency than those nearer to that value. All the distributed values of $\Delta R_{\Delta l}$ are concentrated in the range $-a \leq z \leq a$, where $\underline{z}$ is the value of the random quantity $\Delta R_{\Delta l}$.

Let us now find the mean value of $\Delta R_{\Delta l}$.

$$M(\Delta R_{\Delta l}) = \frac{1}{a\pi}\int_{-a}^{a}\frac{zdz}{\sqrt{1-\left(\frac{z}{a}\right)^2}} =$$

$$= \frac{1}{a\pi}\int_{-a}^{0}\frac{zdz}{\sqrt{1-\left(\frac{z}{a}\right)^2}} + \frac{1}{a\pi}\int_{0}^{a}\frac{zdz}{\sqrt{1-\left(\frac{z}{a}\right)^2}}$$

In the first integral let us make a substitution $z = -u$. Then we shall obtain

$$M(\Delta R_{\Delta l}) = -\frac{1}{a\pi}\int_{0}^{a}\frac{udu}{\sqrt{1-\left(\frac{u}{a}\right)^2}} + \frac{1}{a\pi}\int_{0}^{a}\frac{zdz}{\sqrt{1-\left(\frac{z}{a}\right)^2}} = 0. \tag{8}$$

Next let us find the dispersion $D(\Delta R_{\Delta l}) = \sigma^2(\Delta R_{\Delta l})$.

$$D(\Delta R_{\Delta l}) = \frac{1}{a\pi}\int_{-a}^{a}\frac{z^2dz}{\sqrt{1-\left(\frac{z}{a}\right)^2}}$$

Let us substitute $-z/a = \cos\psi$ and $dz/a = -\sin\psi\, d\psi$.

Then

$$D(\Delta R_{\Delta l}) = \frac{a^2}{\pi}\int_{-\pi}^{0}\frac{\cos^2\psi}{\sin\psi}\sin\psi d\psi = \frac{a^2}{\pi}\int_{0}^{\pi}\cos^2\psi d\psi = \frac{a^2}{2} = \frac{\Delta l^2}{2\cos\alpha}. \tag{9}$$

From (9) let us determine the root mean square deviation:

$$\sigma(\Delta R_{\Delta l}) = \frac{\Delta l}{\sqrt{2}\cos\alpha}. \tag{10}$$

Thus, the effect of the mandrel eccentricity on the accuracy of machining the working surface of conoids amounts to a considerable and unavoidable quantity which must be taken into account when the cams are made.

For details with cylindrical surfaces for which $\alpha = 0$, formula (2) takes the form $\Delta R_{\Delta l} = \Delta l \cos\Theta$, with corresponding changes in the remaining formulas.

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AN INSTRUMENT FOR MEASURING THE ROUGHNESS OF GEAR-TEETH SURFACES

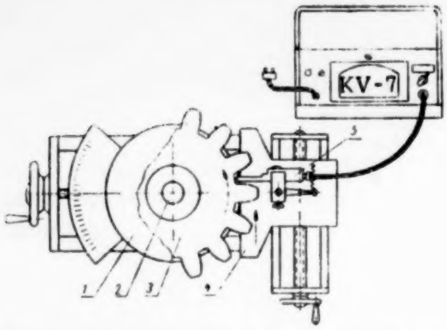
A. P. Nikonorov, L. N. Orlova, and I. V. Tsarev

Translated from Izmeritel'naya Tekhnika, No. 5, p. 14, May, 1960.

The equipment developed by the authors of this article consists of a profilometer KV-7 with a small transducer and an evolventometer MIZ with an individual rolling disk.

The technique of measurement consists in probing the surface of the gear tooth by the needle of the profilometer transducer along a straight line which is produced by the evolventometer.

* See English translation.



1) Rolling disk, 2) mandrel, 3) gear, 4) straight-edge, 5) electrodynamic transducer.

The peculiarity of this method consists in the movement of the surface under test with respect to the supports and the diamond needle of the stationary profilometer transducer (See figure).

The transducer, which is fixed in a holder with a rubber shock-absorber to the measuring lever axle of the evolventometer, does not receive any external vibrations, thus increasing to a great extent the accuracy of measurements.

Deviations from the theoretical involute of the tooth do not affect the accuracy of the profilometer readings, owing to the constant contact of the supports with the surface of the tooth, the free rotation of the axle in the centers, and the position of the supports and the diamond needle on the same line, parallel to the axle.

The shortened cantilever of the profilometer KV-7 transducer provides measurements of the entire surface of a gear tooth with a module of 3.75 mm and over.

The utilization of control mandrels which are intended for checking the involutes of cylindrical gear teeth provides a rapid adjustment of the instrument for checking the accuracy of machining.

A DEVICE FOR ADJUSTING OPTIMETER TABLES

N. V. Sergeev

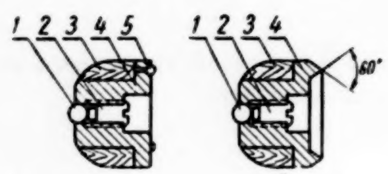
Translated from Izmeritel'naya Tekhnika, No. 5, pp. 14-15, May, 1960

When a tip with a flat measuring surface is fixed to the measuring rod of an optimeter (minimeter, microcator, extensometer, etc.), it is necessary to make this surface strictly parallel with the working surface of the table. Their parallelism is checked with end gauges by means of a technique described in many textbooks and manuals.

Considerably better conditions for measuring parallelism (and, hence, for adjusting the table) are obtained if the contact of the gauge with the tip and the table consists of a point or approaches a point, instead of being a surface contact.

For this purpose we have developed and produced two devices which replace end gauges, one of which (a) is intended for tables with a flat continuous surface, and the other (b) for tables with a ribbed surface. Each one of these devices consists of a 4 mm ball 1, a set screw 2, a body 4 and a heat-insulating (wooden) ring 3.

In the base of the device intended for continuous table surfaces there are three 3 mm balls 5. In the other device the testing surface consists of a sharp circular edge.



The size of the devices is 25 × 20 mm. The technique of checking and adjusting is the same as for end gauges.

MECHANICAL MEASUREMENTS

EFFECT OF THE EXPOSURE TIME ON HARDNESS MEASUREMENTS ON THE HRC SCALE

S. S. Stepanov

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 15-17, May, 1960

The exposure time under full load affects to a considerable extent the measured value of hardness owing both to the continuation of the plastic flow of metal and the deviation from stiffness of the loading and measuring devices of the instrument.

For an experimental investigation of the effect of the exposure time under full load, we have selected three lever instruments made by different firms. These instruments measure hardness of reference gauges for various exposure times under full load.

The time of applying an additional load includes the time of increasing the load from 10 to 150 kg-wt and the time maintained under full load. Both these stages have their own effect on the measured value of hardness. It is difficult to separate them, and therefore, in our experiments the total time was measured, including both stages from the moment the pointer began to move when an additional load was applied, up to the instant the handle of the equipment was lifted in order to take off the additional load.

During the operation the instrument was not subjected to any adjustments; hence, the measurement of the total time was only due to the second stage, and the time of the first stage entered into it as a certain constant term.

Measurements were made with an exposure of 3, 5, 10, 20, 40, and 80 sec. For each exposure time five measurements were made, and their arithmetic mean found and taken as the value of hardness for that exposure. Test results thus obtained were plotted in the form of graphs (Fig. 1) on which the exposure time in seconds was plotted along the x axis, and the hardness (arithmetic mean) for a given exposure along the y axis. The dotted lines parallel to the y axis show the nominal values of hardness gauges under test.

Figure 1 shows curves of three hardness ranges obtained on the same instrument. For other instruments the curves had a similar shape. The positions of the points in Fig. 1 show that the measured relationship is not linear. The two boundary values for this relation follow from the physical meaning of the phenomenon under investigation. In the first place, when the argument (the exposure time) tends to infinity, the function (hardness value) tends to a certain constant value. This tendency can be clearly seen in all the curves. In the second place, when the argument tends to zero, the function must tend to 100 and reach it when $t = 0$. The fulfillment of both conditions leads to a very complicated analytical form of relationship. For practical purposes the second condition can be changed and limited to the requirement of the function reaching 100 for sufficiently small values of the argument, which determine the lower boundary of application of this relationship.

The above requirements are met by the series

$$y = a + \frac{b}{x} + \frac{c}{x^2} + \frac{d}{x^3} + \ldots \tag{1}$$

In the first approximation it is possible to take the first two terms only, i.e., to assume a hyperbolic relation

$$y = a + \frac{b}{x}, \tag{2}$$

where y is hardness (HRC units); x is time (sec); a and b are constant coefficients for a given experiment (a determines a certain ideal hardness for an arbitrarily long exposure time; b, the slope of the curve with a decreasing exposure time).

The coefficients a and b of formula (2) were determined by the least-squares method. The curves plotted from (2) for the three hardness ranges after finding coefficients a and b are shown in Fig. 1 by full lines. The experimental points agree well with these curves. As one would expect, the values of coefficient b decrease with rising hardness.

On the basis of the mean values of a and b, the value of the function y = 100 units is attained for values of argument x equal to 0.06, 0.05, and 0.05 sec for the upper, middle, and lower hardness values, respectively. These values are smaller than the accuracy of exposure time readings by more than one order, and they can be considered negligibly small for these measurements. Hence, the relationship (2) thus obtained in practice also satisfies the second boundary condition.

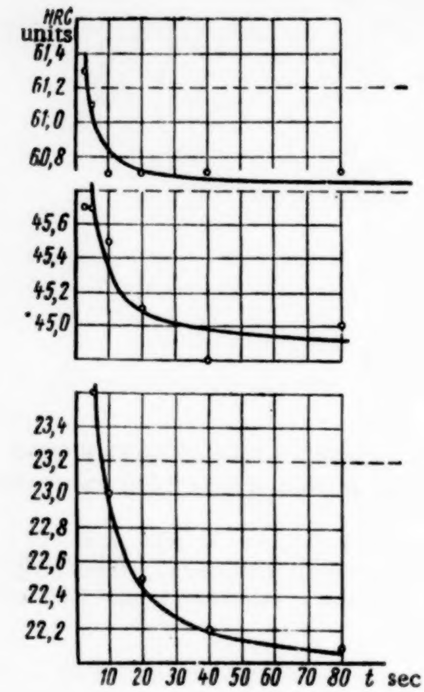


Fig. 1

The actual exposure time has been determined for each hardness range when adjusting under full load. This time corresponds to the abscissas of the crossing point of the above curves (full lines) with the nominal hardness value curves (dotted lines). The values thus obtained are in the range of 3 to 10 sec, which is understandable, since the exposure in adjustment as well as in operation is determined approximately. However, there is a definite tendency to increase the exposure time with a decreasing hardness.

Thus, the effect of the exposure time under full load is expressed in the general case by the equation

$$H = H' + \frac{b'}{t}, \tag{3}$$

where H is the variation of the hardness value for a given exposure time; H' is the actual value of hardness; b' is the mean coefficient which is taken as a constant for the above hardness range.

In order to find the effect of exposure time variations, let us differentiate (3) with respect to t:

$$\frac{\partial H}{\partial t} = -\frac{b'}{t^2}.$$

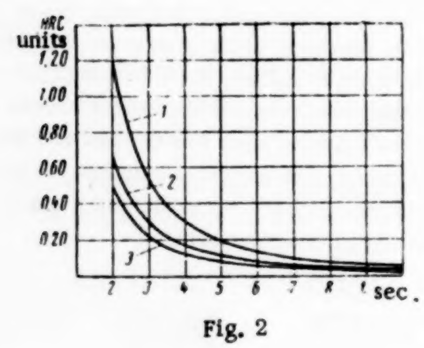


Fig. 2

The error ΔH of the measured hardness due to the variation of time Δt is

$$\Delta H = \frac{\partial H}{\partial t}\Delta t = -\frac{b'}{t^2}\Delta t.$$

If Δt is equal to 1 sec, then

$$\Delta H = -\frac{b'}{t^2}. \tag{4}$$

Hence, the value of the error varies proportionately to the reciprocal of the square of the exposure.

Figure 2 shows the curves of the error of variations with respect to the exposure time for three hardness ranges (1- low hardness; 2- medium; 3- high hardness). The curves are plotted from (4). The exposure time is plotted in seconds along the x axis and the error of the measured hardness value in HRC units, caused by the exposure time deviation of 1 second from the set value, along the y axis. It will be seen from the curves that, for an exposure time of 10 sec, the errors due to the exposure deviations by one second from the set value are small, and even at low hardness values do not exceed 0.05 units. Calculations show that for an exposure of 15 sec these errors are negligibly small for all the hardness ranges.

For an exposure time of 5 sec and less, these errors increase rapidly and attain at 3 sec 0.5 units for a low hardness, 0.3 units for a medium, and 0.2 units for a high hardness value.

SUMMARY

The time of exposure under full load must not be less than 10 ± 1 sec for reference and standard tests, 5 ± 1 sec for calibrations, and 3 ± 1 sec for commercial instruments.

The instruments should be adjusted and used at the same exposure time.

The automation of measurements will provide a greater accuracy and reliability.

A HIGH-SPEED PROGRAMMED ELECTRONIC DECATRON TACHOMETER

I. Ya. Breido and N. K. Ksenzhuk

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The existing tachometers of the mechanical, magnetic, stroboscopic and other types possess in the best case an error of approximately 0.1% [1]. In many instances, however, it is required to measure angular velocities with an error not exceeding 10^{-2}% at a high speed of revolution up to 10^5 rpm. Such an accuracy and resolution are possessed by electric-pulse digital-display tachometers.

The electric-pulse tachometers of this type consist of a magnetic or photoelectric pulse transducer, whose frequency is proportional to the speed of rotation, and a digital-display pulse counter. The required speed of operation and accuracy is possessed by electronic counters, which on that account are most frequently used for the above and other purposes.

The required accuracy in the electric-pulse tachometers is provided by the timer, i.e., a transducer of calibrated time intervals. In practice, the best source of precise time intervals consists of a quartz crystal oscillator, which, in conjunction with a frequency-dividing electronic device, has a very small error which does not exceed 10^{-2}%.

The combined operation of a high-speed counter and a precision timer must be controlled by a suitable electronic automatic device, whose command pulses have sufficiently sharp wave fronts (of the order of fractions of a microsecond).

We describe below an electric-pulse tachometer in which the transducer pulses are registered, and the frequency division is attained by means of decatrons. The tachometer is equipped with a programming device which provides automatic registration of pulses in a given time interval, and then delays the count during the storing interval, after which it restores the readings and starts a new period of registration.

Theprogram data is: a) readout time 1 or 2 sec; b) storing interval, 5, 10 or 15 sec; c) interval between measuring cycles, less than 1 sec.

According to the number of pulses produced by the transducer, the tachometer can measure speeds of rotation of < 0.1 to $2 \cdot 10^4$ rps with an error not exceeding 10^{-2}%. The tachometer operates with input pulses of any

polarity, an amplitude of 0.5 to 80 v, a duration of 5 to 20 μsec and a pulse time of 0.1 to 5 μsec, respectively. The maximum counting speed can slightly exceed 20,000 pps. The error in time intervals does not exceed 10^{-4} sec.

In order to extend the range of the counting periods, a provision is made for working with an external timer.

The electronic equipment consists of the following units (Fig. 1): the input, computer, timer, programming and supply units.

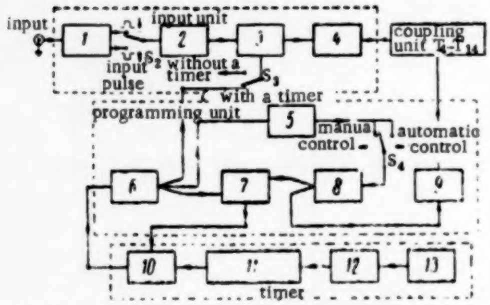

Fig. 1. 1) cathode-anode follower T_{1a}; 2) amplifier-limiter T_{1b}; 3) gating stage, T_2; 4) shaping stage, T_3; 5) controlled multivibrator 5, 10, 15 sec, T_{31}; 6) shaping stage 1, 2 sec, T_{27}, T_{28}; 7) blocking trigger, T_{29}; 8) controlled multivibrator 200 msec, T_{30}; 9) release thyratron, T_{15}; 10) gating stage, T_{26}; 11) frequency divider, T_{19} – T_{25}; 12) shaping stage, T_{18}; 13) quartz crystal oscillator, T_{16}, T_{17}.

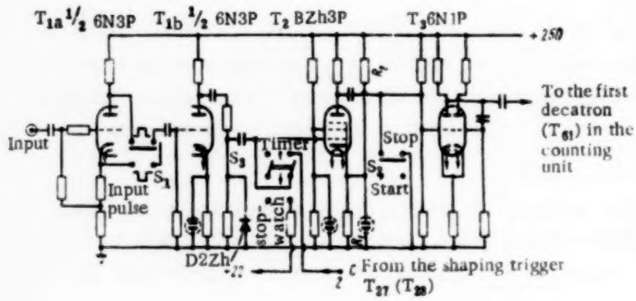

Fig. 2

The input unit, whose schematic is shown in Fig. 2, consists of three electron tubes. The left-hand-side triode of tube T_{1a} serves as a cathode-anode follower and makes it possible to work with a transducer of pulses of any polarity, whose selection is attained by switch S_1. The right-hand-side triode of T_{1b} operates in the amplifier limiter circuit. Pentode T_2 serves for a further shaping of pulses and, in addition, acts as a "gate". Normally, pentode T_2 is blocked by the voltage taken from the potential divider R_1R_2; it is triggered by a positive pulse which is produced by the shaping trigger T_{27} or the conversion trigger T_{28} (see the programming unit schematic in Fig. 4). Contrary to normal practice [2], the gating control in this instrument is attained without buffer stages: the control voltage is fed from the trigger anode to the grid of the gating stage through a potential divider.

Negative pulses are fed from the anode circuit of T_2 to the controlled multivibrator T_3, which has a short restoration time and which forms pulses for triggering the first decatron of the counting unit. The input also contains switches S_2 and S_3, which switch from automatic to manual control with an arbitrary counting time.

The counting unit consists of OG3 decatrons (first stage) and OG5 decatrons (remaining stages). The decatron trigger circuits used in this instrument have already been described [3-5]. The counting unit consists of six stages, thus providing a counting capacity of 1–10^6 pulses.

Restoration of the decatrons to zero before starting the count is carried out by a positive pulse of ~120 v 20 μsec long, fed to the "zero line" to which the guides of all the stages are connected (Fig. 3). The pulse is produced by discharging a condenser into a circuit consisting of thyratron T_{15} and a resistor. The thyratron is tripped by the programming unit, but it can also be triggered by hand with key-switch K_5.

The timer consists of a 10 kc quartz crystal oscillator, a buffer stage, a shaping controlled multivibrator and four frequency-dividing decatron stages. The zero output pin of the last decatron provides pulses at 1 sec intervals fed to the grid of tube T_{26}, which acts as a timer gate. This gate is controlled by the programming unit and is closed for the storing interval (Fig. 1).

In considering the operation of the programming unit, we shall assume that in the initial stage both gates T_2 and T_{26} are open.

From the gating stage of the timer (T_{26}), the short negative pulses at 1 sec intervals are fed to the shaping trigger consisting of a double triode T_{27} (Fig. 4). From the anode circuit of T_{27a} the positive pulses of 1 sec duration (time pulses) are fed either straight to the grid of the gating tube T_2, or to the conversion 2 : 1 stage T_{28}. At

the anode of the left-side triode T_{28}, positive time pulses of 2 sec duration are produced. Switch S_4 serves to select the count time (1 or 2 sec).

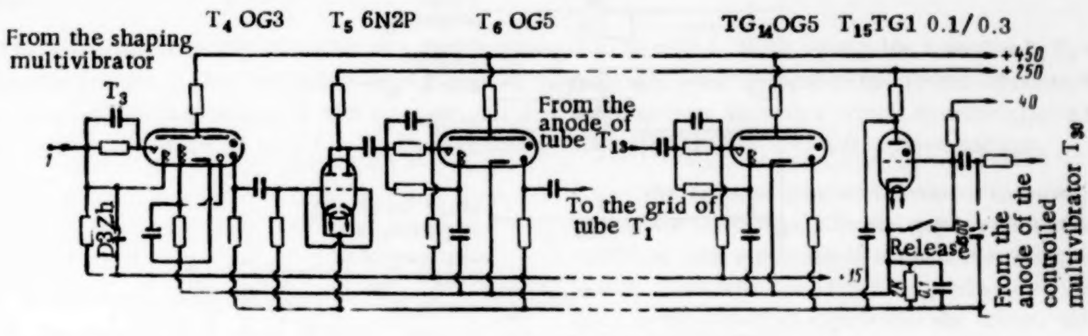

Fig. 3

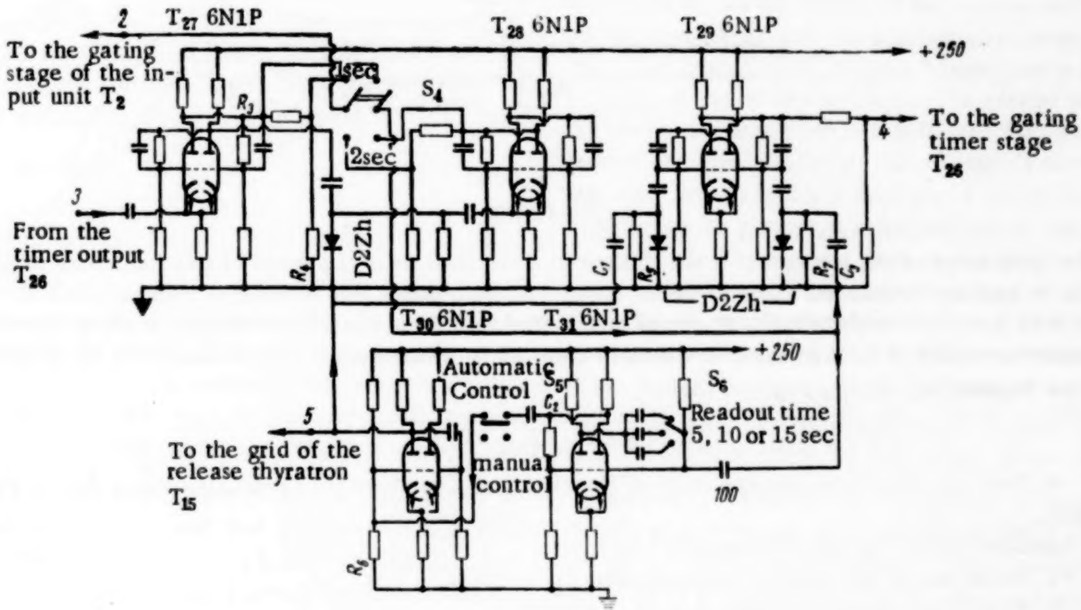

Fig. 4

Time pulses operate gate T_2, making the counting unit register the transducer pulses received at the input of the instrument. At the end of the time pulses, a negative is produced at the output of the differentiating circuit C_3R_7, which is connected to the blocking trigger T_{29}. The normally conducting triode T_{29b} is blocked almost simultaneously ($\pm$ 2 μsec) with the gate T_2. At the same time, triode T_{29a} becomes conducting thus blocking gate T_{26}. Both gates are closed until the blocking trigger T_{29} is returned to its initial condition, which will occur at the end of the storing interval. The latter is set by the controlled multivibrator T_{31}. Triode T_{31b} is conducting in its initial condition; a negative pulse produced by the trailing edge of the time pulse triggers the multivibrator and thus blocks triode T_{31b}. The multivibrator returns to its initial condition in 5, 10 or 15 sec, depending on the capacity in the circuit.

Having restored multivibrator T_{31} to its initial condition, the trailing edge of the pulse in the anode circuit T_{31b} is differentiated by the C_2R_6 network and triggers the controlled multivibrator T_{30}, thus operating triode T_{30a} and blocking T_{30b} for about 200 msec. The positive pulse from the left-hand-side triode T_{30a} is fed to the grid of the blocked thyratron T_{15}, triggers it, and releases the decatrons. The trailing edge of this pulse, which produces a negative overshoot after its differentiation by the C1 R_5 network, trips the blocking trigger T_{29}. Thus, 200 msec after its release, this trigger returns to its initial condition, opening the gate of timer T_{26}.

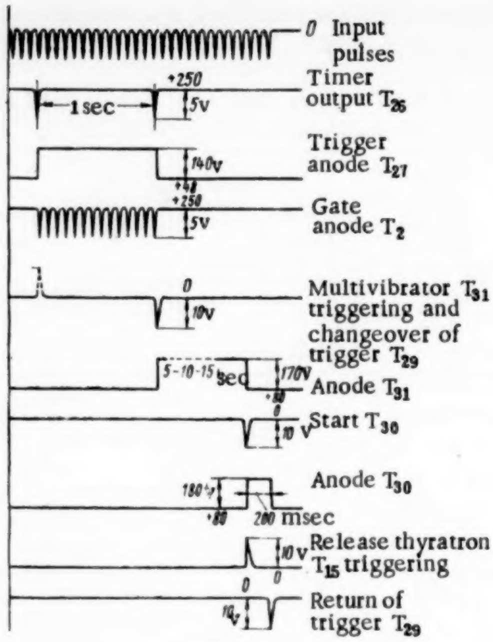

Fig. 5

SUMMARY

The application of the instrument is not limited to measurements of the speed of rotation. With its aid it is possible to measure frequencies up to 20-25 kc, count aperiodic pulses (for instance, of a nuclear particle counter) for $\tau \leq 50$ μsec, and achieve various types of production control in connection with the counting of articles. With a minor extension of the transducer and modification of input switching, it is possible to measure phase relations at low frequencies, the slip angle of motors, etc.

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MEASUREMENTS OF VIBRATIONS AND LINEAR DISPLACEMENTS BY MEANS OF UHF WAVES

K. K. Namitokov and V. F. Chepura

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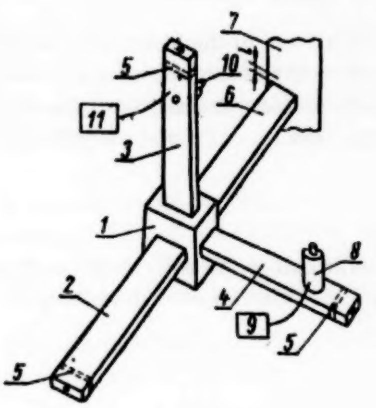
In many experimental investigations of vibrations and linear displacements, the application of transducers encounters technical, and sometimes theoretical, difficulties. For instance, it is not always possible to connect mechanically the transducers with the vibrating system. In such an instance, the method of investigating vibrations by means of centimeter radio waves may be usefully applied. The idea of this method was suggested by Ryan and Summers, who produced an instrument for investigating the shape of a dynamo commutator during operation

[1]. We developed a design and constructed an instrument* for measuring the amplitude and frequency of vibrations of details of various systems, including rotating systems. The instrument has been made of standard units and components.

The instrument (see fig.) consists of a double waveguide T-joint 1, three waveguide branches 2, 3, and 4 with shorting plungers 5, a waveguide branch 6 with an open flange, which is carried up to the vibrating surface 7 under test, a klystron generator 8 with a supply unit 9, a detector head 10 with a crystal detector (DK-S3), an amplifier and oscilloscope 11 type ÉO-7. The klystron generator is supplied with a stabilized voltage.



The klystron generator produces in waveguide branch 4 a wave H_{10}. The plunger is adjusted in the branch in such a position that the wave reflected from it is in phase with the vibrations produced by the klystron at the instant it approaches the latter. Having passed along the waveguide branch 4, the flow of energy is divided into two parts in the T-junction and enters the waveguide branches 2 and 6, thus producing in each of them a H_{10} wave. Since the field phases at the input of these waveguides are the same, no energy penetrates into branch 3 [2]. Object 7 under test is placed at the open end of waveguide 6. The greater part of the energy radiated from it is reflected from the surface of the object back into the waveguide to the T-junction. In waveguide 2 the flow of energy, having approached the plunger, is reflected from it and also returns to the T-junction. Thus, in waveguides 2 and 6 waves with different phases appear at the input to the T-junction. Owing to this phenomenon, a flow of energy arises in waveguide 3, and the detector load registers a voltage. The value of this voltage is determined by the difference in the phase and the value of the reflected wave amplitudes in waveguides 2 and 6, i.e., it depends on the distance l of the surface of the object under test from the end of the waveguide 6, and also on the value and shape of the reflecting surface. For small periodic variations of l (l < 1 mm), the phase of the reflected wave will be mainly affected, thus leading to a periodic variation of the voltage across the detector.

The value of this voltage can be found in the following manner. Assuming that the plunger in waveguide 2 is adjusted in such a way that, with the vibrating surface in a fixed position, the waves in waveguides 2 and 6 at the T-junction are in phase opposition (this adjustment of the plunger is made by setting it to the maximum value of vibrations observed on the screen of the oscilloscope), and the wave amplitudes are equal (which occurs in practice, if $l < 0.05\lambda$), we shall obtain for the voltage across the detector the following expression:

$$v = U\sin\omega t + U\sin(\omega t + 180° + \varphi) = -2U\sin\left(\frac{\varphi}{2}\right)\cos\left(\omega t + \frac{\varphi}{2}\right).$$

where $\varphi = \dfrac{4\pi\Delta l}{\lambda}$ is the wave phase variation in waveguide 6 when the object vibrates with amplitude Δl.

The alternating voltage component at the detector load is

$$E = k2U\sin\frac{2\pi\Delta l}{\lambda};$$

for small values of $\Delta l/\lambda$, we have

$$E = k4\pi U\frac{\Delta l}{\lambda}.$$

where $\underline{k}$ is determined by the detector parameters.

* E. M. Ganapol'skii participated in the work.

Thus, the voltage across the detector load is proportional to the amplitude of vibrations.

This voltage is fed to the amplifier and then the oscilloscope. The oscilloscope screen will display a periodic sequence of pulses whose height is proportional to the amplitude of vibrations. In order to measure the amplitude of vibrations, the instrument should be calibrated by means of an ordinary vibration meter or by measuring vibrations whose amplitude is known. The frequency of vibrations is determined by comparing the repetition frequency of the pulses on the oscilloscope screen with electrical vibrations of a known frequency.

The instrument made by us was tested out in the process of investigating vibrations of details and units of electrical machines. The minimum amplitude of vibrations of these instruments was approximately 0.01 mm. The frequency range of the instrument with respect to higher frequencies is almost unlimited.

The sensitivity of the instrument is determined in the main by the amplitude of the waves in waveguide U, i.e., by the power of the klystron generator and the wavelength λ. The sensitivity of the instrument, therefore, can be raised by using a more powerful and shorter wave klystron. A certain increase in sensitivity can be obtained by raising the gain of the auxiliary narrow-band amplifier. We have used an additional amplifier with a gain of 10.

SUMMARY

The instrument can be used for studying vibrations in nonmetallic details, since the reflection coefficient of centimet radio waves at normal incidence approaches unity for the majority of materials used in industry.

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THERMOTECHNICAL MEASUREMENTS

A NEW METHOD OF ABSOLUTE TEMPERATURE MEASUREMENTS

A. D. Brodskii and A. V. Savateev

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 21-25, May, 1960

In this article we suggest a new method of measuring temperature based on amplitude discrimination and the counting of the number of thermal noise voltage pulses which depends on the value of the absolute temperature of the resistor. The relation between the absolute temperature and number of pulses per unit time at a known value of the threshold of discrimination is given.

The above method makes it possible in theory to measure the temperature over a wide range. Theoretically, the sensitivity of the method increases with decreasing temperature.

The article is a preliminary report on the possibility of measuring the thermodynamic temperature and does not contain an evaluation of its accuracy.

The relation of the rms value $\overline{U}^2_n$ of the thermal noise voltage to the absolute temperature T of resistor R_f in the frequency range df is represented by Nyquist's well-known formula

$$\overline{U}^2_n = 4kT\int_{f_1}^{f_2} R_f df. \tag{1}$$

where k is the Boltzmann constant.

The idea of using thermal noises in resistors for measuring temperatures was published in 1946 [1] and in 1949 it was carried out in practice, when an absolute noise thermometer was made for measuring high temperatures (~1000°C) with an accuracy of 0.1% [2]. In order to raise the accuracy of measurement, a null balancing method was used, which consisted in balancing the rectified value of $\overline{U}^2_n$ in resistor R_0 at a known temperature T_0 by varying R_0 against the rectified value of $\overline{U}^2_n$ in resistor R_x at the measured temperature T_x, determined from the formula

$$\frac{T_x}{T_0} = \frac{R_0}{R_x},$$

which holds when: the registering channel is the same for the noise voltage of R_x and that of R_0; C_xR_x equal C_0R_0, i.e., the time constants of the input circuits are equal; $\overline{U}^2_n \gg \overline{U}^2_{na}$, where $\overline{U}^2_{na}$ is the rms value of the amplifier internal noise.

This method of measuring absolute temperature was adopted in France [3], Federal Republic of Germany [4], and the USA [5], where work in this connection is conducted by the National Bureau of Standards.

In evaluating temperature by the thermal noise method, we propose to use, instead of comparisons and measurements of rectified values of $\overline{U}^2_n$ a recording over a definite interval of time of the number of noise pulse voltages whose amplitude exceeds a set value– that is, to apply in temperature measurements modern methods of experimental physics, by utilizing the statistical nature of the thermal noise electrical pulses.

The possibility of applying in practice for temperature measurements the method of amplitude discrimination and the counting of the number of pulses is illustrated by the noise curves, taken from an oscilloscope screen for two different values of temperature (Figs. 1a and 1b).

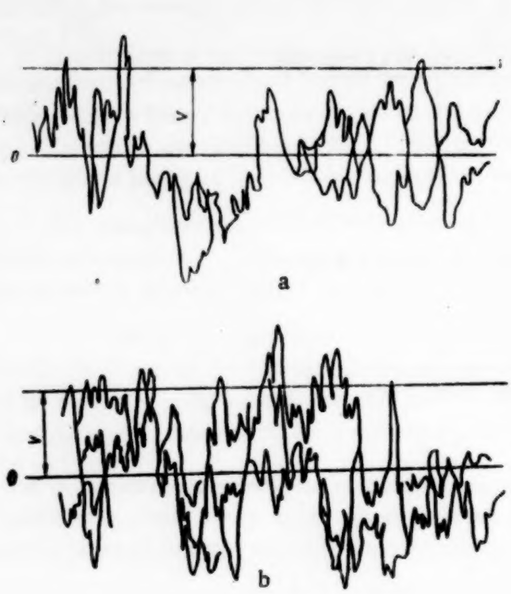

Fig. 1

The above technique is based on the following assumptions:

1. The amplifying device is made in such a way that it has only random noise which follows the normal probability distribution law and cannot be eliminated theoretically. This condition can be satisfied with sufficient accuracy in practice by eliminating or reducing to the minimum the microphonic and flicker effects, industrial and atmospheric interference, and noises due to components which do not satisfy the above condition. This is attained by selecting an appropriate pass-band for the amplifier, by screening, damping and other known means.

2. The value of the resistor which serves as the source of thermal noise is not affected by temperature. This condition can be satisfied to a certain extent either by selecting an appropriate resistance material, which has a small temperature coefficient, or by a combination of two resistors which have equal but opposite temperature coefficients. If this condition cannot be satisfied with a sufficient degree of accuracy, it is necessary to introduce a correction with respect to the variation of the resistance with temperature.

If this first condition is satisfied, the following expression for the rms values of the amplifier noise voltages referred to the grid of the tube will hold;

$$\overline{U}^2_{n} = \overline{U}^2_{tn} + \overline{U}^2_{gn} + \overline{U}^2_{an} \tag{2}$$

where $\overline{U}^2_n$ corresponds to the total amplifier noise; $\overline{U}^2_{tn}$ corresponds to the grid leakage resistance thermal noise of the amplifier valve, this resistance serving as an element which is affected by temperature changes; $\overline{U}^2_{gn}$ corresponds to the noise produced by fluctuations of the grid current in the grid leakage resistance of the amplifier tube; $\overline{U}^2_{an}$ corresponds to the remaining amplifier noise referred to the grid of the tube and including the tube shot noise.

In applying (1) and (2) and assuming a constant frequency characteristic of the amplifier, a constant temperature (thermostatic control), and the fulfilling of the second condition, it can be shown that the formula for the rms value of the total amplifier noise voltage at its output will have the form

$$\overline{U}^2_{n\,out} = (b+d)+cT, \tag{3}$$
$$b=\overline{U}^2_{an\,out} \quad d=\overline{U}^2_{gn\,out} \quad cT=\overline{U}^2_{tn\,out}$$

Coefficients b, c, and d represent instrument constants which should be determined.

The conversion from the rms value of the noise voltage to the number of noise voltage pulses whose amplitude exceeds a set value can be easily accomplished by means of the formula [6, 7] which determines the probability of the amplitude values in the range of V to V + dV:

$$P(V)\,dV = \frac{V}{\overline{U}^2_n} e^{-\frac{V^2}{2\overline{U}^2_n}}\,dV. \tag{4}$$

This formula only applies over a restricted frequency range. This condition can be easily satisfied by making the frequency characteristic of the high-frequency amplifier of a band-pass type. This is also necessary from

the point of view of optimum conditions which make it possible to increase the ratio of $\bar{U}^2_{tn}$ to $\bar{U}^2_{an} + \bar{U}^2_{gn}$, thus raising the accuracy and sensitivity of this method.

Integrating (4) between the limits of V and ∞ where V is the value of the threshold of discrimination, we shall obtain a formula of the probability of the noise envelope with an amplitude in the range of V to ∞:

$$P(>V)=e^{-\frac{V^2}{2\bar{U}^2_n}} \tag{5}$$

It is obvious that the number of noise pulse voltages per unit of time whose amplitude exceeds V will be proportional to P (> V):

$$N=DP(>V)=De^{-\frac{V^2}{2\bar{U}^2_n}}, \tag{6}$$

where D is the coefficient of proportionality which depends on the spectral density of noise in the passband of the amplifier (in [7] this is $\omega_{II}/2\pi$):

$$\ln N=a-\frac{V^2}{2(b+d+cT)}, \tag{7}$$

where

$$a = \ln D$$

With respect to T we finally obtain

$$T=\frac{\frac{1}{2}V^2-(b+d)(a-\ln N)}{c(a-\ln N)}. \tag{8}$$

The absolute values of the noise thermometer constants a, b, c, and d can be calculated. It is, however, more reliable to determine them experimentally by means of the following tests.

Experiment 1. With the grid of the first tube shorted, the number of pulses N_1 and N_2, which correspond to the two values of the threshold of discrimination V_1 and V_2, are determined.

From (7) we obtain

$$\ln N_1=a-\frac{V_1^2}{2b}, \qquad \ln N_2=a-\frac{V_2^2}{2b},$$

(c = d = 0, since the grid leakage resistance is equal to zero).

From these equations we find a and b:

$$b=\frac{V_1^2-V_2^2}{2(\ln N_2-\ln N_1)}, \tag{9}$$

$$a=\ln N_i+\frac{V_i^2}{2b}; \quad (i=1,2). \tag{10}$$

Experiment 2. The number of pulses N_3 is determined which corresponds to the threshold of discrimination V_3 at such a high temperature T_1 that it is possible to neglect the internal noises of the amplifier, preserving a high degree of accuracy. Then

$$\ln N_3\simeq a-\frac{V_3^2}{2cT_1}; \quad (b+d\ll cT_1).$$

whence

$$c \simeq \frac{V_3^2}{2T_1(a-\ln N_3)}. \tag{11}$$

Calculations have shown that

$$c_{act} - c_{ap} = -\frac{b+d}{T_1} \tag{12}$$

where c_{ap} is the approximate value of c found from (11), and c_{act} is the actual value of c which would have been obtained if we had not neglected at temperature T_1 the internal noises of the amplifier.

It follows from (12) that for a more precise determination of c, it is necessary to decrease the internal noise of the amplifier, which is attained by selecting optimum conditions and increasing the temperature T_1 at which the experiment is conducted.

Experiment 3. The number of pulses N_4 which corresponds to the value of the threshold of discrimination V_4 at the treble water point temperature T_0 is determined. Then

$$\ln N_4 = a - \frac{V_4^2}{2(b+d+cT_0)}. \tag{12a}$$

whence

$$d = \frac{V_4^2 - 2(a-\ln N_4)(b+cT_0)}{2(a-\ln N_4)}. \tag{13}$$

Thus, from the value of two known temperatures T_1 and T_0 required for the experimental determination of the instrument constants, we obtain the possibility of measuring absolute temperature by the method of amplitude discrimination and the counting of the number of noise voltage pulses. The value of the measured temperature is calculated from (8).

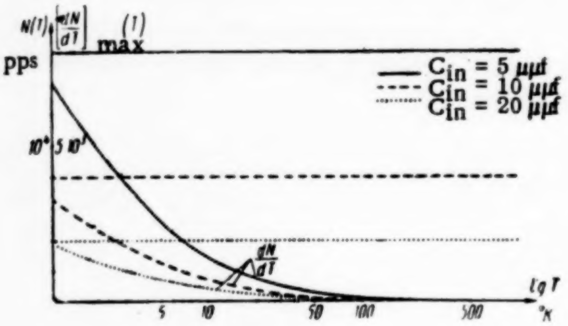

Fig. 2

The sensitivity of the above method of measuring temperature depends in the first place on the value of dN/dT. Differentiating (7) with respect to T, we obtain

$$\frac{dN}{dT} = \frac{1}{2} DcV^2 \frac{e^{-\frac{V^2}{2(g+cT)}}}{(g+cT)^2} \tag{14}$$

where

$$g = b + d.$$

The maximum sensitivity of this method (determined by $[dN/dT]_{max}$ is attained when, in measuring the temperature, the value of the threshold of discrimination is established according to the formula

$$V = V_{opt} = \sqrt{2(g+cT)}. \tag{15}$$

Then

$$\left[\frac{dN}{dT}\right]_{max} = \frac{Dc}{e} \cdot \frac{1}{g+cT}. \tag{16}$$

where e is the base of natural logarithms.

It will be seen from (16) that the sensitivity of this method rises with decreasing temperature. This fact permits one to assume that the above method should theoretically be most efficient for low temperature measurements, contrary to the method used in [2].

Figure 2 shows the curves of the calculated relation between N (T) and $[dN/dT]_{max}$ (T), obtained for optimum conditions with the suggested ideal band-pass frequency characteristic of the amplifier.

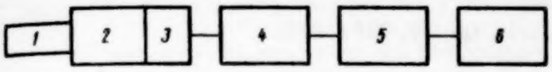

Fig. 3. 1) temperature transducer; 2) preamplifier; 3) band-pass filter; 4) amplifier; 5) amplitude discriminator; 6) conversion circuit.

It will be seen from the curves that a relatively high sensitivity is obtained for this method at low temperatures (~1500 pulses/ sec · deg at T = 10.0°K and $C_{in} = 5\mu\mu f$), and that the sensitivity is affected to a considerable degree by the input capacity C_{in}.

The accuracy of temperature measurements is limited by the statistical dispersion in the value of the number of noise pulses at a given temperature. It is, naturally, possible to raise the accuracy by increasing the measuring time. The effect of equipment errors on the accuracy of measurements is the subject of further studies.

The block schematic of a noise thermometer is shown in Fig. 3. In order to be able to measure the temperature by the above method with great precision, each unit of the pulse noise thermometer must satisfy the requirements listed below.

The temperature transducer must be screened, have the smallest possible input capacity and an optimum value of the grid leakage resistance, which produces thermal noise.

The preamplifier should have a minimum internal noise (including microphonic noise), a maximum stability of gain, good screening and a linear amplitude characteristic. The band-pass frequency characteristic of the amplifying channel should be optimal.

The amplitude discriminator should possess a high resolution ($t_{res} \leq 1$ μsec), a stable and adjustable threshold of discrimination and the capacity to form at its output standard П-shaped short pulses (≤ 10 μsec).

The conversion circuit must have a high resolution ($t_{res} \simeq 1$μsec) and counting rate (≥ 10^4 pps).

The installation for preliminary experimental investigations consisted of the available laboratory equipment.

Figure 4 shows a transducer which is well screened, has a small self-capacity (~3 μμf) and can be immersed in any medium.

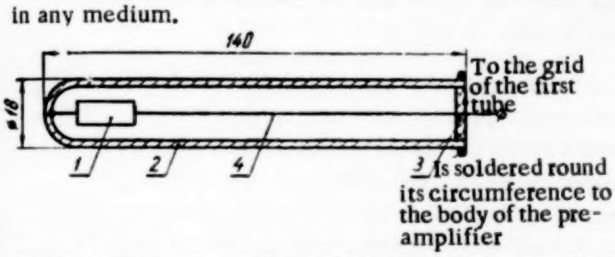

Fig. 4. 1) Resistor type MLT, 510 kohms; 2) a copper foil screen, 0.10 mm; 3) a getinax* washer; 4) a copper wire 0.12 mm in diameter.

The counting of noise pulses was done by means of a mass-produced conversion computer type PS-10000 with a time resolution of 1 μsec.

Since, in the preliminary experiments, the aim was to check the principle of the method, special attention was not paid to accuracy or stability. Temperature values obtained by this method were compared with those provided by a reference thermometer. The experiment consisted in measuring the temperature of a thermostat. With a threshold of discrimination of 14.1 v, the mean value of the number of pulses amounted to 265525, which is equivalent to a temperature of 20.25°C.

According to the preliminary data, the difference in determining temperature by this method and by means of a reference thermometer (20.2°C) is within the measurement tolerances.

SUMMARY

Preliminary experimental data shows the possibility of measuring temperature by the number of voltage noise pulses. In theory, this method provides absolute and comparative temperature measurements over a wide range: the upper limit being that at which the resistor is destroyed; the lower boundary, in theory, is limited by the superconductivity temperature of the resistor material. The sensitivity of the method rises with decreasing temperatures.

There are reasons to believe that by counting pulses over a longer period of time with highly stable temperature fields and amplifier gain with an adjustable threshold of discrimination, it will be possible to raise the absolute accuracy of temperature measurements as compared with other existing methods.

* A complex plastic insulating material [Publisher's note].

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MEASUREMENTS OF THE PISTON TEMPERATURE OF HIGH-SPEED INTERNAL COMBUSTION ENGINES

R. V. Kazachkov

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Measurement of piston temperatures by means of thermocouples is one of the most widespread existing methods. Normally, the temperature of slow-moving pistons is determined by means of thermocouples with a permanent connection to the measuring instrument. The main defect of this method consists of the unreliable lead-out of thermocouple electrodes from the piston to the measuring instrument. For measuring the temperature of high-speed pistons, thermocouples with a periodic connection to measuring instruments are normally used. Then it is difficult, however, to establish a reliable contacting device.

The schematic of an electrical circuit developed by the author of this article for measuring with sufficient precision, sensitivity and reliability the temperature of pistons is shown in Fig. 1.

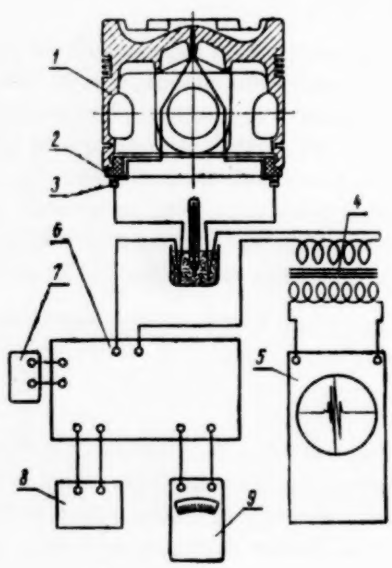

Fig. 1

The leads of the chromel-alumel thermocouple mounted in piston 1 are connected to fixed contacts 2, which touch the spring contacts 3 at the bottom dead-center position. The travel of the spring contacts amounts to 0.5-0.8 mm, which corresponds to 15-18° of the crankshaft rotation. One of the thermocouple leads includes a transformer 4 which acts as a simple amplifier (its voltage ratio is 80). The secondary winding of the transformer is connected to the input of a cathode-ray oscilloscope 5 type ÉO-7. When the primary winding circuit of the transformer is disconnected, a voltage is induced in the secondary, and observed in the form of bumps of a certain shape on the oscilloscope screen. The thermal emf is measured by means of a high-resistance potentiometer 6 type PPTV-1. When the current in the thermocouple circuit is completely balanced out, the bumps on the oscilloscope screen disappear. The temperature of the cold junction is measured with a mercury-in-glass thermometer with 0.1°C graduations. The working current of battery 8 is set by means of a standard cell 7 and a null-indicat-

ing mirror galvanometer 9 (type GPZ-47 with graduations of $8.9 \cdot 10^{-8}$ amp/ division). Owing to the use of a step-up transformer and an electronic oscilloscope, a sufficiently high sensitivity is obtained. The threshold of sensitivity of the device amounts to 0.1 mv, which corresponds in chromel-alumel thermocouples to 2.5°C.

The device for measuring the temperature of pistons (Fig. 2) consists of the thermocouples with their fixed contacts, the spring contact brackets and leads to the brackets.

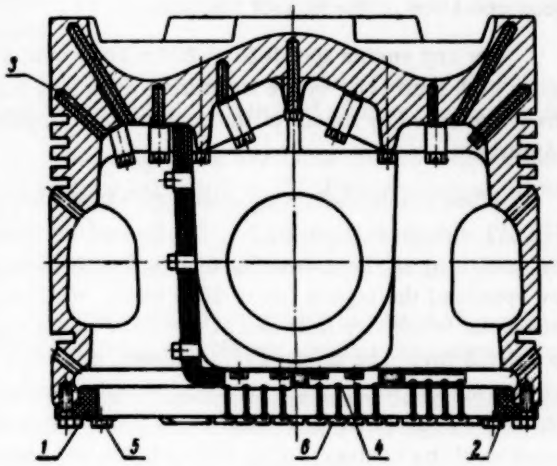

Fig. 2

The piston contains (Fig. 2) 12 chromel-alumel thermocouples 3 made of wires insulated with glass fiber.

The thermocouples are placed inside thin brass tubes which are forced into holes in the piston and calked in, thus providing a good contact between the hot junction and the piston and a secure fixing of the thermocouple; the hot junctions are at a depth of 1 mm from the external surface of the piston. The hot-junction ball is soldered to the end of the tube and placed at an angle of 120°.

The thermocouple leads are fixed on the inside surface of the piston by means of brackets 4 and screws 5. All the alumel wires are taken to one side of block 1, with its fixed contacts, and the chromel wires to the other side. The thermocouple wires are connected to the fixed contacts 6 mounted on a textolite ring 2. The wires should not hang loosely anywhere, since that will lead to their speedy deterioration. The end surfaces of the fixed contacts are strictly perpendicular to the sides of the piston. In order to ensure a smooth transition of the spring contact to the neutral position, two sloping plates are provided on the textolite ring.

The bracket with the spring contacts (Fig. 3) is placed in a special boring at the top of the crankcase, and is fixed to the external surface of the cylinder. It consists of a steel bushing 4 with two textolite contact blocks 1 which are fixed to the bushing by bolts 2. Along its entire perimeter the bushing is covered with a textolite band 5 whose grooves engage with the wire drive from the cantilever control. Each contact block has a steel socket 3 into which body 6 of the spring contact is fitted. Such a construction makes it possible to adjust the travel of the spring contact; this adjustment is important, since the sum of the dimensional variations in various components along the cylinder axis (the upper housing, block, case, crankshaft, connecting rod, piston) may amount under unfavorable conditions to a deviation from the normal size of up to 1 mm. Rods 7 of the spring contacts are made of the same materials as the thermocouples of chromel and alumel, and their springs 8 of steel. The thermocouple conductors which are fixed directly to the spring contact rods are made in the shape of helixes, thus raising considerably the reliability of their operation.

The cantilever drive of the spring contacts (Fig. 4) operates in the following manner. In the neutral position the spring contacts are disengaged and do not operate. In order to measure the emf of any of the thermocouples, it is necessary to place the spring contacts against the corresponding contacts on the piston. This is done by turning the spring contact holder with respect to the cylinder axis by means of the two wire drives 1.

The wires are also used as leadouts for the thermocouples and are, therefore, made of chromel and alumel. Each of these wires is fixed to the contact blocks by means of bolts 2 and directly connected to the helical thermocouple leads. The wires are then taken through insulating stoppers into the grooves of the textolite band which encircles the steel bushing over its entire perimeter (5 in Fig. 3). One of the wires runs in the upper, and the other in the lower, groove. Thus, the wires are in two parallel planes and cannot short. Through an opening at the top of the crankcase, the wires are taken out to a textolite flywheel which has grooves to hold the wires. The wires are fixed to the flywheel by means of two clamps 3. The flywheel is secured in the required position by means of a catch 4. The spring contacts are switched by releasing the catch and turning it until it engages in the notched disk 5 opposite the required thermocouple (each notch is numbered according to the corresponding thermocouple). When the flywheel is turned, one of the wires is wound round it and rotates the spring contact holder. The displacement of the spring contacts with respect to the piston contacts is gradual, due to the following reasons: the

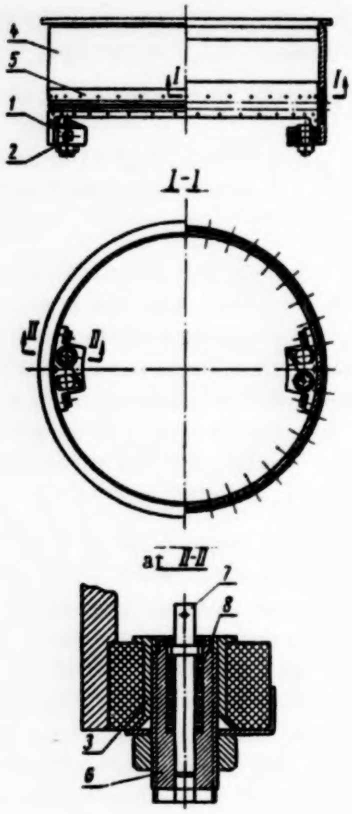

Fig. 3

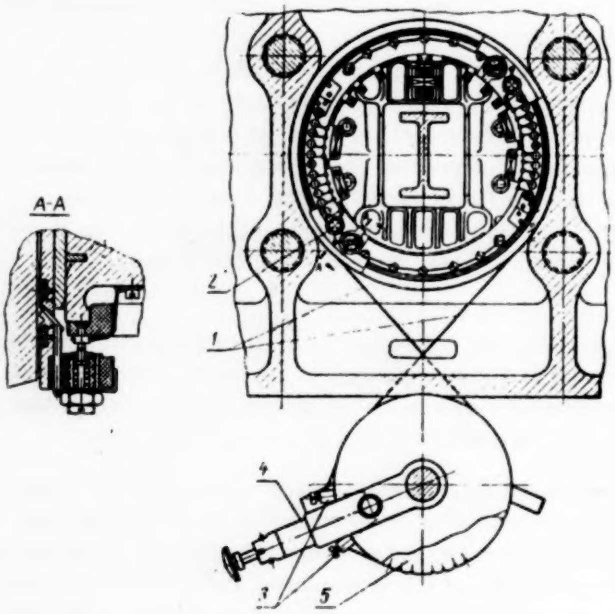

Fig. 4

contacts touch each other for a short time only (some 0.002 sec), the contacts are liberally oiled, the diameter of the spring contact plungers is considerable larger than the gap between the piston contacts.

Test have shown that the thermocouple current curve closely approximates a rectangular shape and the breaking of the circuit cannot be observed, thus showing a good operation of the impact contacts.

For any engine speeds ($n = 800 - 2000$ rpm) a fairly high sensitivity of the measuring device of 0.1 mv is preserved by means of the oscilloscope amplifier adjustment.

When a null-indicating mirror galvanometer, type GPZ-47 with graduations of $8.9 \cdot 10^{-8}$ amp/div, is used, the sensitivity of the measuring device hardly alters for low speeds of the engine (up to 1000 rpm). With rising speeds the sensitivity falls and, at $n = 1500$ rpm, amounts to 0.2-0.3 mv. The mirror galvanometer, due to its inertia, reads the mean value of thermocouple current, which is $\varphi/360$ of its maximum value (where φ is the duration of the contact) This fact explains the loss of sensitivity. It is inconvenient to use a null-indicating mirror galvanometer for testing machines (it is sensitive to vibrations); moreover, it is difficult to observe the scale through a small-size eyepiece.

SUMMARY

1. By means of this device, with impact contact, it is possible to measure piston temperatures with an error of ± 2.5°C, which is satisfactory for engine testing.

2. The device works reliably at high engine speeds ($n = 1500$ rpm). The high reliability is ensured by the fact that, at transitional periods of the engine operation, the contacts can be placed in a nonoperating position.

3. The design of the device makes it possible to measure piston temperatures not only on experimental portions of engines, but on complete engines as well, which is very important, since the operation of a complete engine (especially a supercharged one) differs considerably from that of an experimental portion.

4. The basic elements of the device can be successfully used in designing and adjusting devices for measuring piston temperatures of complete high-speed engines, piston high-pressure compressors and piston gas generators.

UTILIZATION OF ALUMINUM FOR CALIBRATING FIRST-GRADE THERMOCOUPLES

E. S. Shpigel'man

Translated from Izmeritel'nayaTekhnika, No. 5, pp. 28-29, May, 1960

The Institute of the Committee of Standards, Measures and Measuring Instruments calibrates first-grade thermocouples by means of three reference points—the temperatures of solidification of zinc, antimony and copper.

The International Temperature Scale Regulation of 1948 recommends as a secondary reference point the temperature of solidification of aluminum equal to 660.1°C.

According to the available printed information [1], the substitution of antimony by aluminum will not produce an error exceeding 0.1°C if the impurities in the metal do not exceed 0.02%.

We have investigated the possibility of using aluminum of standard Soviet grades for calibrating first-grade thermocouples instead of antimony, which is in short supply.

Aluminum of three grades of purity: AB_{000} – 99.998%, A_{00} – 99.82%, and A_0 – 99.71% was investigated. Aluminum AB_{000} completely satisfies the metrological requirements with respect to its purity.

The solidification temperature of aluminum was determined in the usual manner in a shaft oven used for obtaining reference points. Since aluminum combines easily with silica and alumina, the protective quartz tube with the thermocouple was placed in a specially made graphite jacket before being immersed in the molten metal. The graphite jacket consists of a cylindrical tube with an internal diameter of 7 mm and walls 1 mm thick; the closed end of the jacket has the shape of a truncated cone 30 mm high. In order to establish a reducing atmosphere when the metal is melted, the surface of aluminum was covered with graphite dust. Moreover, the diameter of the opening in the crucible cover was made to fit tightly round the jacket. By a light pressure on the quartz tube, the jacket was immersed in the molten metal until its tip touched the bottom of the crucible. The quartz tube was fixed in this position by means of a special stand attached to the oven. The graphite jacket was left in this position after the aluminum solidified.

The temperature gradient between the internal surface of the graphite jacket and the quartz tube was determined by means of a differential platinum-platinorhodium thermocouple (at the temperature of aluminum solidification); this gradient was in practice equal to zero.

It was found experimentally that the solidification temperature of aluminum can be easily reproduced. The cooling curves of the three grades of aluminum have a sufficiently large flat portion (for the aluminum grade AB_{000} it is over 20 min). Thus, from the point of view of a stable phase change temperature, each of the three investigated grades of aluminum can be used as a reference point for calibrating first-grade thermocouples.

The solidifying temperature of aluminum was determined by three first-grade thermocouples. The mean solidifying temperature for aluminum grade AB_{000} was determined as 660.1_8°C, for grades A_{00} and A_0, as 658.9_5°C and 658.6_5°C, respectively.

In order to compare the accuracy of calibration of first-grade thermocouples by means of solidification temperatures of zinc, aluminum, copper, antimony and copper and zinc, five thermocouples were calibrated (SÉ-65, SÉ-4, SÉ-13, 5-58, and 1-58), the thermocouples with the indexes SÉ were calibrated at the All-Union Scientific Research Institute of Metrology (VNIIM) by means of the solidification temperatures of zinc, antimony and copper.

On the basis of the calibration data obtained, we calculated from the interpolation equation of the form $l = a + bt + ct^2$ the values of the thermal emfs from 300 to 1200°C.

Calibration data for three first-grade thermocouples are given in the table by way of an example. For two of the thermocouples, the data obtained by the VNIIM was used.

It will be seen from the table that the maximum difference the thermal emf values obtained by means of two different solidification temperatures (that of aluminum and antimony) amounts to 0.0007 mv (0.07°C) for the SÉ-65 thermocouple, 0.0004 mv (0.04°C) for the SÉ-4 thermocouple and 0.0008 mv (0.08°C) for the 1-58 thermo-

t°C	SÉ-65		SÉ-4		1-58	
	KhGIMIP Zn, Al, Cu	VNIIM Zn, Sb, Cu	KhGIMIP Zn, Al, Cu	VNIIM Zn, Sb, Cu	KhGIMIP Zn, Al, Cu	KhGIMIP Zn, Sb, Cu
300	2.314_3	2.314_9	2.316_0	2.315_9	2.307_4	2.308_0
400	3.253_9	3.254_0	3.254_1	3.254_1	3.246_9	3.246_9
500	4.226_8	4.226_5	4.225_9	4.226_0	4.219_8	4.219_5
600	5.232_7	5.232_5	5.231_2	5.231_6	5.226_0	5.225_4
700	6.272_7	6.272_0	6.270_6	6.270_8	6.265_7	6.265_0
800	7.345_7	7.345_0	7.343_6	7.343_9	7.338_7	7.338_0
900	8.452_1	8.451_5	8.450_3	8.450_6	8.445_0	8.444_4
1000	9.591_7	9.591_4	9.590_8	9.590_9	9.584_7	9.584_4
1100	10.765_0	10.764_8	10.764_9	10.764_9	10.757_7	10.757_8
1200	11.971_4	11.971_8	11.972_9	11.972_7	11.964_0	11.964_8

couple. These data show that by calibrating the thermocouples by means of the solidification temperatures of zinc, aluminum and copper instead of zinc, antimony and copper, no additional errors are introduced in practice, since the differences in the emf values do not exceed the random errors involved in the calibration of first-grade thermocouples.

SUMMARY

Since supercooling is not characteristic of aluminum, the flat portion of its cooling curve is twice as large as that of antimony. This circumstance makes it possible to increase the number of thermocouples calibrated for one smelting of aluminum, thus lowering considerably the expenditure of time and money on the calibration of thermocouples.

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MEASUREMENTS OF TEMPERATURE CONDUCTIVITY BY THE METHOD OF RADIAL TEMPERATURE WAVES IN A CYLINDER

Yu. A. Kirichenko
Translated from Izmeritel'naya Tekhnika, No. 5, pp. 29-32, May, 1960

A new method of measuring temperature conductivity based on the regular third-order thermal condition for an unlimited cylinder was proposed by A. N. Gordov [1] and, on his suggestion, tested out by V. A. Moskalev [2]. The method consists of establishing a periodic temperature oscillation on the surface of a cylindrical sample made of the material under test, and of determining, by the ratio of the first harmonic amplitudes of temperature oscillations at a distance r from axis (A_r) and on axis (A_0), the value of the criterion quantity • $Pd_r = \frac{\omega}{a} r^2$ from the relation

$$\frac{A_r}{A_0} = \left(\mathrm{ber}^2 \sqrt{Pd_r} + \mathrm{bei}^2 \sqrt{Pd_r}\right)^{\frac{1}{2}}, \tag{1}$$

and then the temperature conductivity from the formula

$$a = \frac{\omega}{Pd_r} r^2, \tag{2}$$

where ber x and bei x are Thompson functions which are determined by the relation $I_0(x\sqrt{i}) = \mathrm{ber}\, x + i\,\mathrm{bei}\, x$; ($I_0(x)$ is a modified Bessel function of the first kind and zeroth order); $\omega = 2\pi f$, f being the frequency of temperature oscillations.

• This notation of the criterion value was introduced by A. V. Lykov [4].

This method makes it possible to determine temperature conductivity by means of one instrument over a wide range of temperatures for samples of different sizes and materials which differ greatly in their temperature conductivity.

Let us evaluate the error of this method on the basis of (1) and (2), i.e., assuming that the theoretical conditions are being fulfilled for which formula (1) was derived; that there is a regular third-order condition, the coefficient of temperature conductivity of the sample, its thermal dissipation, and the temperature oscillation amplitude of the medium are constant during the experiment, the sample consists of an unlimited cylinder and the temperature measuring devices do not distort the temperature field of the sample.

Assuming that the errors $\Delta\omega$, Δr, and ΔPd_r are of a purely random nature, we shall obtain from (2) an expression for the relative error:

$$\frac{\Delta a}{a} = \left[\left(\frac{\Delta Pd_r}{Pd_r}\right)^2 + \left(\frac{\Delta\omega}{\omega}\right)^2 + 4\left(\frac{\Delta r}{r}\right)^2\right]^{\frac{1}{2}} \tag{3}$$

The value of $\Delta Pd_r / Pd_r$ is found from (1):

$$\frac{\Delta Pd_r}{Pd_r} = 2\left[\left(\frac{\Delta A_r}{A_r}\right)^2 + \left(\frac{\Delta A_0}{A_0}\right)^2\right]^{\frac{1}{2}} \times \frac{\mathrm{ber}^2\sqrt{Pd_r} + \mathrm{bei}^2\sqrt{Pd_r}}{\sqrt{Pd_r}\,(\mathrm{ber}\sqrt{Pd_r}\,\mathrm{ber}'\sqrt{Pd_r} + \mathrm{bei}\sqrt{Pd_r}\,\mathrm{bei}'\sqrt{Pd_r})} =$$

$$= \left[\left(\frac{\Delta A_r}{A_r}\right)^2 + \left(\frac{\Delta A_0}{A_0}\right)^2\right]^{\frac{1}{2}} F(\sqrt{Pd_r}). \tag{4}$$

The values of $F(\sqrt{Pd_r})$ with respect to $\sqrt{Pd_r}$ are shown in the table.

$\sqrt{Pd_r}$	1	1.5	2	2.5	3	3.5	4	4.5	5	6	7	8	9
$F(\sqrt{Pd_r})$	33.2	7.24	2.91	1.70	1.24	1.00	0.88	0.75	0.64	0.54	0.45	0.39	0.35

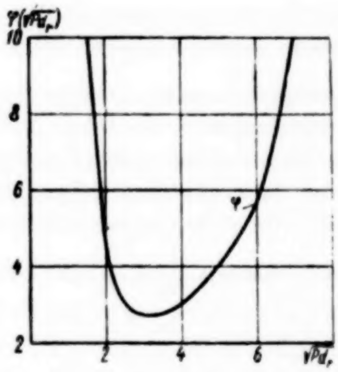

Fig. 1. The value of $\frac{\Delta Pd_r}{Pd_r} / \frac{\Delta A_r}{A_r}$ for equal absolute measurement errors of temperature oscillation amplitudes [$\varphi(\sqrt{Pd_r})$].

For equal absolute errors of temperature oscillation measurements ($\Delta A_r = \Delta A_0$), a condition which is common in practice, it is possible to represent (4) in the form

$$\frac{\Delta Pd_r}{Pd_r} = \frac{\Delta A_r}{A_r}\left[1 + \left(\frac{A_r}{A_0}\right)^2\right]^{\frac{1}{2}} F\left(\sqrt{Pd_r}\right) =$$

$$= \frac{\Delta A_r}{A_r}\,\varphi(\sqrt{Pd_r}). \tag{5}$$

It will be seen from the graph of function $\varphi(\sqrt{Pd_r})$ (Fig. 1) that the optimum value of criterion Pd_r lies in the range of 6 to 15. The minimum error will occur at $Pd_r \simeq 9$ or for $A_r / A_0 \simeq 2$.

In the particular case of equal relative amplitude errors ($\frac{\Delta A_r}{A_r} = \frac{\Delta A_0}{A_0}$), we obtain

$$\frac{\Delta Pd_r}{Pd_r} = \frac{\Delta A_r}{A_r}\sqrt{2}\,F(\sqrt{Pd_r}). \tag{6}$$

The position of the central thermal probe has practically no effect on the temperature conductivity measurements. In fact, if the coordinate of the central thermal probe is $r' = \Delta r_0$, the measured ratio of amplitude vibrations $\frac{A_r}{A_r'} = \frac{A_r}{A_0} / \frac{A_r'}{A_0}$ will differ from the calculated value by a factor A_0 / A_r', which approaches unity. For an optimum value of $\sqrt{Pd_r} = 3$, the deviation of the thermal probe from the axis by 15% ($r'/r = 0.15$) will produce a measurement error in the amplitude ratios of less than 0.1% ($A_r/A_0 = 1.0007$).

Figure 2 shows schematically the possible design of samples. The holes for temperature measuring devices are placed in the longitudinal, and not the radial, direction in order to decrease the distortion in the temperature field of the sample, and to avoid placing the temperature measuring devices in regions with large temperature gradients. Sample c is detachable; the position of the temperature measuring devices is more precisely defined than in the preceding two samples (a and b). In sample d the second temperature measuring device is placed on the surface of the cylinder.

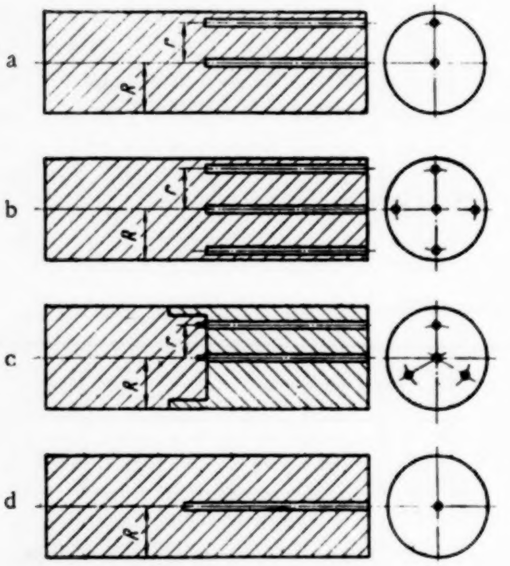

Fig. 2

If we assume the external radius of the sample to be R = 20 mm, experience shows that the error Δr in measuring the distance between the temperature measuring devices for each type of sample is equal to ± 0.5 mm (a and b), ± 0.2 mm (c), and ± 0.1 mm (d), and hence, the relative error will be equal, respectively, to 2.5% (a), 1.2% (b), 0.7% (c), and 0.5% (d).

Measurements of larger amplitudes can be provided without great difficulty with a relative error of ΔA_r, which does not exceed 0.5%. For $\Delta A_0 = \Delta A_r$, this will lead to an error of $\Delta Pd_r / Pd_r = 1.5\%$. The error $\Delta\omega$ in measuring the frequency can be neglected: then the total error of temperature conductivity measurements will amount to 5% (a), 3% (b), 2% (c), and 2% (d), for each of the cases under consideration.

Thus, the expected accuracy of measuring temperature conductivity by the method of radial temperature waves is not lower than the most accurate attainable measurement of temperature conductivity at high temperatures (~1000°C) and is equal to ~5% [3].

An increased length of the samples makes the construction of the heating oven more complicated and raises the difficulty of mounting temperature measuring devices and of determining their position. Let us now find the minimum length of a cylinder $2l$ for a given radius R or the ratio $\delta = R/2l$ for which the cylindrical sample can be considered infinitely long for a given degree of accuracy. Let us consider the temperature field of the cylinder as the resultant of two temperature waves: a cylindrical one, dissipated at the ends and an end one dissipated over the surface of the cylinder. Let us determine the error due to the end effects $\Delta_1 (\frac{A_r}{A_0}) / \frac{A_r}{A_0}$ for small values of the Biot criterion. In this instance the dissipation of the cylindrical and end waves can be neglected, and the maximum value of the error evaluated from the ratio of amplitude of oscillations in the center of a plate $2l$ thick to the amplitude of oscillations at the axis of an infinite cylinder of radius R, which have on their surface the same amplitude of temperature oscillations as the sample under test. Applying the following formula for determining the attenuation of the waves in the plate:

$$\frac{B_l}{B_0} = \left(\sin^2 \sqrt{\frac{1}{2} Pd_l}\, \mathrm{sh}^2 \sqrt{\frac{1}{2} Pd_l} + \cos^2 \sqrt{\frac{1}{2} Pd_l}\, \mathrm{ch}^2 \sqrt{\frac{1}{2} Pd_l}\right)^{-\frac{1}{2}}. \tag{7}$$

(here $Pd_l = \frac{\omega}{a} l^2$), which can be easily obtained by solving the problem of the plate by means of an operational method [4], we shall obtain

$$\max \Delta_1 \left(\frac{A_R}{A_0} \right) \Bigg/ \frac{A_R}{A_0} \simeq \frac{A_R}{A_0} \Bigg/ \frac{B_l}{B_0} \simeq \frac{B_0}{A_0}. \tag{8}$$

The relation of max $\Delta_1 (\frac{A_R}{A_0}) / \frac{A_R}{A_0}$ to Pd_r and δ, calculated from (8), is shown in Fig. 3. If the permissible error $\Delta_1 (\frac{A_R}{A_0}) / \frac{A_R}{A_0}$ is limited to 0.5%, we shall obtain for the optimum value of $\sqrt{Pd_r} = 3$ a value of $\delta \leq 1/3$. The comparison of data obtained by means of the above approximate evaluation with the data obtained by a precise solution of the problem of temperature variations in a limited cylinder [5] shows that the above evaluation is sufficiently accurate for any values of the Biot criterion.

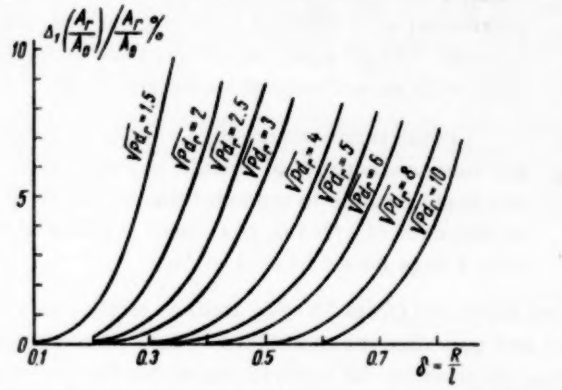

Fig. 3. The relation between the error, due to the limited size of the sample, and the ratio of the radius to half the cylinder length for various values of $\sqrt{Pd_r}$.

In order to produce a periodically changing temperature on the surface of the sample, ovens with small thermal inertia were used, and these consisted of quartz tubes wound with nichrome wire with a thin asbestos insulation. (Their length was 1 m, internal diameter 55 - 65 mm). The samples were placed in an isothermal part of the oven on special supports. The oven was supplied with a stabilized voltage controlled by means of autotransformers. The oven was switched in and out of circuit at equal intervals of time by means of a variator, a device which consisted of a synchronous motor, a reduction gear, and cams driven by it, one of which connected, and the other one disconnected, the oven. The variator produces current oscillations in the oven winding and, hence, temperature oscillations with a period from 5 sec to 1 hr. In order to decrease temperature oscillations at high temperatures, only part of the power supplied to the oven was switched on and off. After 2-3 hr following the beginning of the variator operation, the sample acquires a regular third-order thermal condition when the registration of temperature oscillations can be started in the central portion and the portions of the sample removed from the axis.

The higher harmonics of the temperature variations are attenuated within the system consisting of the sample and the oven; yet the measured oscillation amplitudes differed in our experiments from the first harmonic by 3-12%. For accurate measurements it is necessary, therefore, either to place the temperature measuring devices at a very large distance from the surface of the cylinder, or use harmonic analysis in determining the value of the first harmonic amplitude.

The temperature variations were measured by means of thermocouples or resistance thermometers. When thermocouples were used, measurements were made simultaneously at the axis of the sample (Fig. 2c) and at a distance r from the axis at four points, and the results were averaged. The emf of thermocouples was measured on potentiometer KL-48 or recorded on an electronic automatic potentiometer. In the latter case, the mean value of the emf was compensated by a voltage supplied to the thermocouple circuit from a special battery.

The resistance thermometers have a certain advantage as compared with thermocouples: the coordinate of the external thermometer is accurately determined by the radius of the sample; the thermometers "integrate" the surface temperature, and the possible irregularities of the temperature field have little effect on the measurements; resistance thermometers provide a higher sensitivity than thermocouples, which is important in automatic recording. Their disadvantages consist in a complicated mounting and the difficulties arising in calibrating the external thermometer.

Measurements by means of resistance thermometers were carried out on a sample with a single axial opening (Fig. 2d) into which the internal thermometer was forced. Its sensing element 15-20 mm long and 3 mm in diameter consisted of several layers of copper 0.05 mm wire insulated from each other with a bakelite lacquer.

A metal rod served as the basis of the thermometer; its jacket was made of aluminum foil. The second thermometer was wound directly onto the sample cylinder surface in its middle portion. The whole sample was covered by an even layer of bakelite lacquer. Thermometers of such a design were used at temperatures up to 100°C. This design can also be used for higher temperatures if a more heat-resisting insulation is employed.

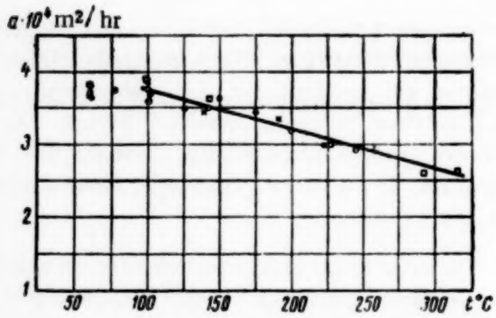

Fig. 4. The relation of the thermal conductivity of Kel-F to temperature. □ a sample 25 mm in diameter; ●, O, and x-samples 30 mm in diameter with an oscillating period of 17.52 min, 26.27 min, and 11.68 min, respectively.

Measurements by means of resistance thermometers were made with bridge MVL-47, or recorded automatically. In automatic recording each thermometer was connected to an arm of a separate bridge with 3 constant arms, which were balanced at a thermometer resistance corresponding to the mean temperature of the experiment; the values of the imbalance obtained at each bridge circuit were fed to the input of a double-channel electronic potentiometer ÉPP-09. The circuit parameters were selected so as to make the ratios of the recorded voltages equal the temperature oscillation ratios with an accuracy of a constant factor.

In the temperature range of 20-120°C the temperature conductivity of ebonite was measured, and it was found possible to represent the conductivity with an rms error of ±(3-4)% as a linear function of temperature: $a = (4.54 - 0.0141\ t)\ m^2/hr$.

Measurements were made with samples of different diameters (from 25 to 55 mm) at oscillation periods ranging from 12 min to 1 hr by means of thermocouples and resistance thermometers. Check measurements of the temperature conductivity by the acalorimeter method [3] provided the same results within the specified limits of accuracy.

The temperature conductivity of Kel-F was measured in the temperature range of 60-300°C (Fig. 4). It is linear with an accuracy of ±(2.5-3.5)% in the range of 100 to 300°C, and is represented by $a = (4.30 - 0.0054\ t)\ m^2/hr$. At 60°C its value is equal to $(3.7 \pm 0.1) m^2/hr$. Measurements were made by means of thermocouples on samples 25-30 mm in diameter.

SUMMARY

The analysis of errors, confirmed experimentally, shows that, for measurements under optimum conditions, the absolute value of temperature conductivity can be easily obtained by the radial temperature wave method with an accuracy of ~3% over a very wide temperature range. These optimum conditions consist in providing that $Pd_r \simeq 9$ and that the ratio of the diameter to the length of the sample ~1:3. The experiment is not complicated and can be made completely automatic. This method can be recommended for badly conducting materials which can be easily machined (for instance, plastics).

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A RESISTANCE THERMOMETER MADE FROM A SPARKING PLUG

Yu. N. Gogin
Translated from Izmeritel'naya Tekhnika, No. 5, p. 32, May, 1960

In measuring temperatures inside tubes and vessels operating under pressure, difficulties arise in placing resistance thermometers inside these objects and bringing their leads out. It is very convenient to use for this purpose the insulator and the body of an automobile sparking plug 18 mm in diameter. The central electrode of the plug is screwed out or drilled out and replaced by a metal rod 4 mm in diameter. This rod is secured in the body of the insulator by BF-2 glue and nuts (part of the insulator in the lower portion of the plug is chipped away). The part of the rod which protrudes below the low edge of the plug is covered with a glass tube which is fixed by a nut. The resistance thermometer is wound over the glass tube in one or in several layers insulated from each other, and its leadouts are connected to the body of the plug and the central rod. When a multilayer winding is used,it is more convenient to have an odd number of layers so that the leadouts appear at different ends of the glass tube.

When the temperature of a noncorroding, nonconducting medium is measured, and when there is no danger and mechanical damage, the above thermometer does not require a metal jacket and, hence, will have but a small thermal inertia.

ELECTRICAL MEASUREMENTS

MEASUREMENT OF VECTOR ELECTRICAL QUANTITIES

V. G. Pustynnikov and N. Kh. Shatskii

Translated from Izmeritel'nayaTekhnika, No. 5, pp. 33-35. May, 1960

In order to measure the modulus, argument and components of a vector electrical quantity in a given complex plane, we have developed vector-measuring devices on the basis of a differential phase-sensitive amplifier.

The electronic vector device with a rotating field provided by a stator winding consists of a measuring element and a special phase regulator.

The measured vectorial electrical quantity is fed to the input of the measuring element; at the output the components of this quantity are provided.

The special phase regulator which feeds the measuring element provides two different voltages, which are displaced with respect to each other 90°, and form the complex plane of the measuring element between whose axes the input variable is examined.

The same phase regulator is used for controlling over wide limits the position of the axes of this complex plane.

The phase regulator (Fig. 1) consists of a stator, which has a three-phase double-pole winding C intended to produce a rotating magnetic field, and a rotor on whose iron cylinder, which is located inside the stator, coils K_1 and K_2 are wound at an angle of 90° to each other in such a manner that each side of the coil lies in a separate longitudinal groove. The rotating magnetic field of the stator three-phase winding induces in coil K_1 an emf $E_{a1} \simeq U_{a1}$, and in coil K_2 an emf $E_{a2} \simeq U_{a2}$, which have a phase difference of 90° between them.

When the rotor is turned through an angle φ, the voltages U_{a1} and U_{a2} will change their phase by the same angle. Moreover, the phase difference between them will remain equal to $\pi/2$.

In order to determine angle φ through which the rotor has been turned and, hence, the phase angles of voltages U_{a1} and U_{a2} with respect to a certain initial position, the device is supplied with a scale.

The direction of the voltage vector $\bar{U}_{a1} = U_{a1} e^{jo}$ in coil K_1 is taken as a positive direction of the real axis, and direction $\bar{U}_{a22} = U_{a2} e^{j\pi/2}$ in coil K_2 is taken as the positive direction of the imaginary axis.

The counterclockwise rotation of the phase regulator is considered to be positive and the reference line for calculating the angle of rotation of these coils coincides with the positive direction of the real axis.

Thus, by changing the position of coils K_1 and K_2 in the rotating magnetic field, it is possible to orientate the real and imaginary axes of the complex variable plane in the required position, and examine the measured electrical quantity U_{in} with respect to that plane.

The measuring element of the vector-measuring device contains two electronic phase-sensitive amplifiers, each of which consists of a double triode. The anode circuits of double triode T_1 are fed by the output voltage U_{a1} of the phase regulator, and those of double triode T_2 by the voltage of phase regulator U_{a2} (Fig. 1).

The measured vector electrical quantity is transformed at the input of the amplifiers by a grid potential divider $R_{\partial 1}$ and $R_{\partial 2}$ into two voltages with a phase difference of 180° between them, so that one of them coincides with vector U_{in} and the other is in phase opposition.

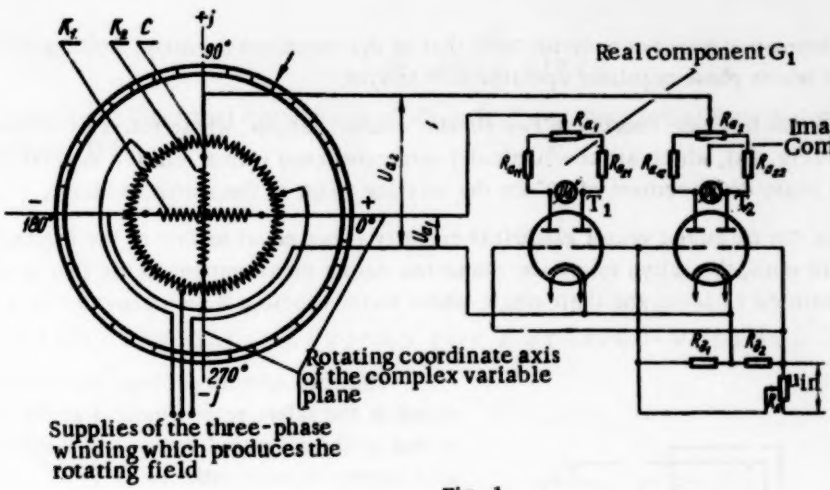

Fig. 1

These voltages are fed to the grids of the phase-sensitive amplifiers which provide at their outputs the components of the measured vector in terms of the complex plane axes.

Moving coil microammeters G_1 and G_2 are connected directly to the output anodes of each tube and used as voltage indicators.

Voltmeter G_1 of tube T_1 reads voltage U_a, which is equal to the difference in the voltage drop across equal anode load resistors R_{a11} and R_{a21}.

$U_a = KU_{in} \cos \varphi$ [1] is proportional to the projection of the input voltage (U_{in}) onto the axis of the given complex variable plane (i.e., on the direction of the voltage vector in coil K_1) and the gain K of the device. Voltmeter G_2 of the tube T_2 reads voltage U_b, which is equal to the difference of voltage drops across equal resistors R_{a12} and R_{a22}. $U_b = KU_{in} \sin \varphi$ is proportional to the projection of the input voltage onto the imaginary axis of the same complex variable plane (i.e., on the direction of the voltage vector in coil K_2).

In order to avoid the effect of inaccurate balancing of the triode parameters on the operation of the circuit, variable resistors R_{a1} and R_{a2} are provided.

When the rotor shaft carrying coils K_1 and K_2 is turned through a certain angle, the axes of the complex variable plane rotate through the same angle. Thus the projections on the axes + (−) and +j (−j) of vector U_{in} also change as indicated by the pointer voltmeters G_1 and G_2.

For a more precise determination of the modulus and the argument of the measured electrical quantity by means of the above equipment, it is necessary to make the real axis of the complex variable plane coincide with vector U_{in}, i.e., to rotate the rotor of the phase regulator, and with it voltages U_{a1} and U_{a2} which determine the direction of the complex plane axes, from the given position until the imaginary component becomes zero, which indicates the coincidence of vector U_{in} with the real axis.

Moreover, the angle of rotation of the phase regulator read off its scale will be equal to the phase angle of the measured quantity with respect to the zero position of the real axis, and the voltmeter of tube T_1 will indicate

$$U_a = KU_{in} \cos 0^\circ = KU_{in}$$

i.e., the modulus of vector U_{in}.

The above vector-measuring device can be used for plotting amplitude, and phase−frequency characteristics, for automatic control of the position of the rotor in a synchronous motor, for maintaining a constant cos φ in synchronous machines, for carrying out mathematical operations on vector quantities, etc.

The main defect of the above vector-measuring device consists in its limited range of application: it can only be used when the frequency of the measured quantity U_{in} coincides with that of the anode voltages U_{a1} and U_{a2}.

When the mains frequency does not coincide with that of the measured quantity, we suggest the use of a phase-measuring device whose phase regulator operates with selsyns.

The phase regulator in this case consists of two similar contact selsyns, whose rotors have three-phase, double-pole windings 1 (Fig. 2a), which are mechanically interconnected with a relative angular displacement of 90°, thus providing a phase displacement of 90° for the rotating fields of the above windings.

If the frequency of the measured vector electrical quantity is not equal to that of the mains, from which the phase regulator could work, the selsyn rotors are connected during measurement to the source which provides the frequency of the measured variable, and their single-phase stator windings 2 are connected to a source of direct current.

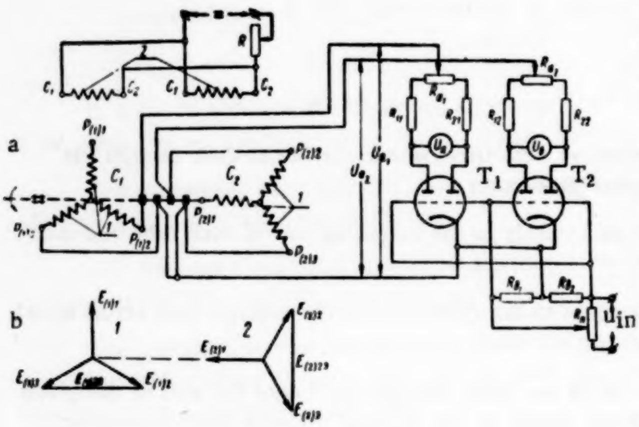

Fig. 2

Thus, two systems of three-phase emfs are induced in the selsyn rotor windings at the same frequency as that of the measured vector, and displaced in phase with respect to each other by 90°.

Similar line voltages in each of these emf systems (Fig. 2b) are used for feeding the anode circuits of tubes T_1 and T_2. Moreover, the line voltage $\dot{E}_{(1)23} = E_{(1)}e^{j0} = U_{a1}$ of the three-phase system (Fig. 2b) is taken as the positive direction of the real axis, and line voltage $\dot{E}_{(2)23} = E_{(2)}e^{j\pi/2} = U_{a2}$ of the second three-phase system is taken as coinciding with the direction of the imaginary axis.

A simultaneous variation of the output voltage phase is provided by turning the stator winding of the selsyns.

If the frequency of the measured vector quantity coincides with that of the mains, the rotor windings 1 of both selsyns are supplied with the three-phase voltage (Fig. 3), with a similar phase rotation in both, and the stator voltages are used for feeding the anode circuits.

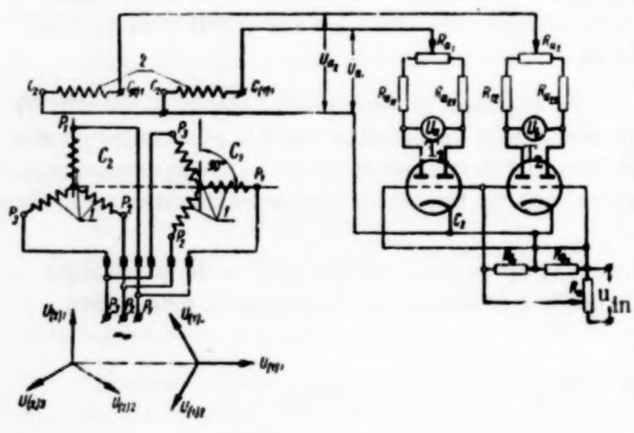

Fig. 3

Since the selsyn rotors are at 90° to each other, the emfs $E_{a1} \simeq U_{a1}$ and $E_{a2} \simeq U_{a2}$ induced in the stator windings 2 will also be displaced with respect to each other by 90°.

When the mechanically connected rotors of the selsyns are rotated, the stator output voltages will rotate through the same angle, preserving the phase difference of 90° between them.

In order to be able to determine the phase rotation of the output voltages U_{a1} and U_{a2}, the phase regulator is supplied with a scale calibrated according to the principle of a vector-measuring device with a rotating magnetic field induced by the stator winding.

The accuracy of operation of the measuring element of the above devices depends to a great extent on the degree of imbalance of the triode characteristics in the circuit. For this reason, before each measurement, the circuit must be balanced in order to compensate the deviation of the triode parameters by means of the variable anode load resistors.

In order to avoid the effect of tube parameter dispersions on the operation of the device, it is advisable to select experimentally tubes with similar parameters by means of plotting their anode characteristics, since the initial balancing does not always eliminate the error of measurement due to the dispersion of the tube parameters (the case of crossing characteristics).

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CIRCUIT PARAMETER CALCULATIONS FOR A STEPPED-VOLTAGE REFERENCE GENERATOR

M. A. Zemel'man
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In converters of voltages from an analog to a digital form, side by side with reference generators of linear changing voltages, those of stepped voltages are also used [1].

We have not come across a description of the technique for designing these generators so as to ensure small errors in the output voltage. The aim of the present work is to analyze the operation of a reference stepped voltage generator operating in a "diode pump" circuit, and establishing a criterion for selecting parameters of its basic elements.

The generator schematic is shown in Fig. 1.

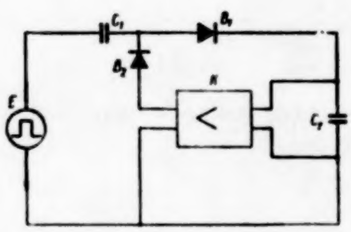

Fig. 1

Here E is the amplitude of the rectangular pulses of duration τ, and frequency $f = 1/T$; K is an amplifier whose input impedance is very large and output impedance very small.

When the first voltage pulse E is received, it makes rectifier B_1 conducting and blocks rectifier B_2; the voltage across the capacitor C_2 becomes

$$V_{21} = V_0 = E\frac{C_1}{C_1+C_2}, \qquad (1)$$

and, across C_1,

$$V_{11} = E\frac{C_2}{C_1+C_2} = \frac{C_2}{C_1}V_0. \qquad (2)$$

Let us assume that the output impedance of the source of voltage E is very small. During intervals between the E pulses, rectifier B_1 is blocked and rectifier B_2 conducting. If we assume that the amplifier input impedance is infinite, then capacitor C_2 will not discharge during the interval, and capacitor C_1 will discharge through rectifier B_2 and the output impedances of the voltage source and the amplifier. When there is no amplifier in the circuit (K = 0), the capacitor C_1 will discharge completely (providing the time constant of the circuit is sufficiently small). When the next pulse is received, the voltage change across capacitor C_2 will be a little smaller than V_0, since the initial (at the instant the second pulse is received) voltage across capacitor C_2 was not zero, and that across C_1 was zero. With a consecutive reception of E pulses the voltage across capacitor C_2 will have the shape of rising steps with each succeeding step decreasing in size.

When the gain of the amplifier is equal to unity (K = 1), the voltage at the output of the amplifier during the whole of the pulse sequence (including the interval) is equal to V_0. Therefore, during the interval, capacitor C_1 does not discharge to zero, but is recharged to voltage $-V_0$. Thus, with the reception of the next pulse, the increment of the voltage across capacitor C_2 will again be equal to V_0, i. e., the voltage across it will become equal to $2V_0$. Thus, with a gain of K = 1, the output voltage of the circuit, i.e, the voltage across capacitor C_2,

assumes the shape of a rising stepped curve with all the steps of the same size and equal to V_0. This serves as the basis for using this circuit as a reference stepped voltage generator.

Under actual conditions, it is impossible to obtain such a strictly regular "ideal" shape of a curve. The basic theoretical reasons for making the shape of the curve deviate from the ideal are the deviation of the gain from unity (which always occurs to a certain extent) and the finite value of the amplifier input impedance. There are also other factors affecting the output voltage (the deviation from zero of the output impedance of the amplifier and that of the source of voltage E, the difference between the characteristics of rectifiers B_1 and B_2 and that of an ideal switch), but they are of a secondary nature not peculiar to this circuit, and in the majority of cases, can be corrected in the adjustment of the circuit.

It is interesting to investigate the relation of the circuit output voltage to the gain of the amplifier and the resistor shunting capacitor C_2:

1. The effect of the deviation of gain from unity. Let us introduce the following assumptions: that the internal impedance of the source E is zero, the input impedance of the amplifier is infinite and its output impedance zero, the rectifiers act as ideal switches, i.e., their forward resistance is zero and their reversed resistance is infinite; that $C_1 \ll C_2$, which always holds in practice (see below), and that gain $K = 1-\Delta$, where $\Delta \ll 1$.

The circuit shown in Fig. 1 meets these conditions. During the operation of the first pulse ($\tau > t > 0$), rectifier B_1 is conducting, and rectifier B_2 blocked (Fig. 2).

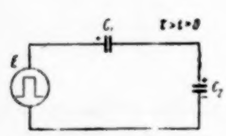

Fig. 2

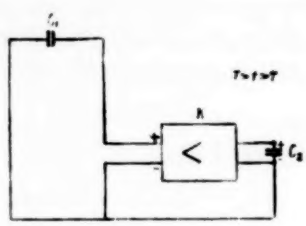

Fig. 3

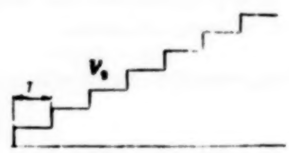

Fig. 4

It was pointed out previously that during the reception of the first pulse (τ), the voltage across capacitor C_2 is [see (1)]

$$V_{21}=V_0,$$

and the voltage across capacitor C_1 is [see (2)]

$$V_{11}=\frac{C_2}{C_1}V_0.$$

Moreover, $V_{21} \ll V_{11}$, and the voltages have the signs shown in Fig. 2. Since $V_{21} \ll V_{11}$, rectifier B_1 will become blocked and B_2 conducting at the instant the pulse comes to an end. Hence, during the interval, the circuit will look like the one shown in Fig. 3. According to the adopted assumptions, capacitor C_2 does not discharge during the interval, the output voltage of the amplifier during the interval is constant and equal to KV_{21}, and capacitor C_1 rapidly recharges up to that voltage. For a more general consideration of this case, let us assume that in addition to the voltage KV_{21}, there is also a noise voltage V_{no} at the output of the amplifier. The voltage across the capacitor C_1 during the interval will then be

$$V'_{11}=V_{21}(1-\Delta)+V_{no} \tag{3}$$

The voltage across capacitor C_2 will remain equal to

$$V'_{21}=V_0. \tag{4}$$

At $t = T$ the second pulse is received, and the circuit again assumes the form shown in Fig. 2. The initial voltages across the capacitors are, however, no longer equal to zero, but are determined by Equations (3) and (4). At the instant the second pulse is received, the circuit has voltages V'_{11}, V'_{21}, and E. In order to determine the stable voltage across capacitor C_2, let us use the superposition method, considering this voltage as the sum of two components.

The first component is determined by the initial voltage across the capacitors connected in the circuit showin in Fig. 2 at $E = 0$; the second component is equal to voltage E.

The first component can be determined in the following manner. The initial charges across the capacitors C_1 and C_2 are

$$q_1 = C_1 V'_{11}; \quad q_2 = C_2 V'_{21}.$$

The total charge of the capacitors connected in parallel when $E = 0$ (Fig. 2) is equal to $Q = q_1 + Q_2$ and the total capacity $C = C_1 + C_2$. Hence, the voltage across the capacitors will be

$$V^* = \frac{Q}{C} = \frac{C_1 V'_{11} + C_2 V'_{21}}{C_1 + C_2}$$

or, considering (1), (3), and (4),

$$V^* = V_0 \left[1 - \frac{C_1}{C_1 + C_2} \left(\Delta - \frac{V_{no}}{V_0} \right) \right]. \tag{5}$$

The second component across capacitor C_2 is determined by expression (1). Hence, the voltage across capacitor C_2 during the entire second period of pulsation is

$$V_{22} = 2V_0 - V_0 \frac{C_1}{C_1 + C_2} \left(\Delta - \frac{V_{no}}{V_0} \right). \tag{6}$$

The voltage across capacitor C_1 during the second interval is

$$V'_{12} = V_{22}(1 - \Delta) + V_{no} \tag{7}$$

A general formula for the train of pulses can be obtained on the basis of the following considerations. At the beginning of the $(n + 1)$th pulse, the voltage across capacitor C_2 will become

$$V_{2\,(n+1)} = V_0 + \frac{Q}{C} = V_0 + \frac{C_1 V'_{1n} + C_2 V_{2n}}{C_1 + C_2}, \tag{8}$$

where V'_{1n} is the voltage across capacitor C_1 during the interval of the preceding nth period; V_{2n} is the voltage across capacitor C_2 during the nth period.

Taking (3) into consideration, it is possible to write

$$V'_{1n} = V_{2n}(1 - \Delta) + V_{no} \tag{9}$$

After simple transformations, we obtain

$$V_{2\,(n+1)} = V_0 + V_{2n} \left[1 - \frac{C_1}{C_1 + C_2} \left(\Delta - \frac{V_{no}}{V_{2n}} \right) \right]. \tag{10}$$

Solving (10) for each period, it is possible to see that, during the nth period, the voltage across the capacitor C_2 is expressed in the following manner:

$$V_{2n} = nV_0 - \frac{C_1}{C_1 + C_2} e_n, \tag{11}$$

where

$$e_n = \left[(n-1)^2 - \sum_{p=1}^{n-2} p \right] V_0 \Delta - (n-1) V_{no} \tag{12}$$

Considering that

$$\sum_{p=1}^{n-2} p=\frac{(n-1)(n-2)}{2},$$

we will have, after simple transformations,

$$\varepsilon_n=(n-1)\,V_0\left(\frac{n}{2}\Delta-\frac{V_{no}}{V_0}\right). \tag{13}$$

If the amplifier has no noise ($V_{no} = 0$) and its gain is precisely one ($\Delta = 0$), $\epsilon_n = 0$ and

$$V_{2n}=nV_0, \tag{14}$$

i.e., the voltage across capacitor C_2 has the form shown in Fig. 4, and all the steps are of the same size equal to V_0.

The deviation of the voltage at the nth period from the value $V_{2n} = nV_0$, i. e., the error of the output voltage is determined by the value of ϵ_n.

The relative voltage error is

$$\delta=\frac{\frac{C_1}{C_1+C_2}\varepsilon_n}{nV_0}=\frac{C_1}{C_1+C_2}\cdot\frac{(n-1)}{n}\left(\frac{n}{2}\Delta-\frac{V_{no}}{V_0}\right). \tag{15}$$

For $n \gg 1$, and considering that $C_1 \ll C_2$ and that the noise voltage can have different signs, we have

$$\delta=\frac{C_1}{C_2}\left(\frac{n}{2}\Delta\pm\frac{V_{no}}{V_0}\right). \tag{16}$$

or

$$\delta=\frac{C_1}{C_2}\frac{n}{2}\Delta\pm\frac{V_{no}}{E}. \tag{16a}$$

In order to make this error sufficiently small, it is necessary to preserve the inequality $C_1 \ll C_2$; also the inequality $V_0 \ll E$. The amplifier should have $V_{no} < V_0$ and hence, $V_{no} \ll E$. Under these conditions we may consider that

$$\delta\simeq\frac{C_1}{C_2}\frac{n}{2}\Delta. \tag{17}$$

If there is no amplifier in the circuit, i.e., if $K = 0$, and $\Delta = 1$, the relative error of the output voltage is

$$\delta=\frac{C_1}{C_2}\frac{n}{2}. \tag{18}$$

Expression (18) can also be obtained from a direct examination of the circuit without an amplifier.

Expression (17) represents the connection between parameters of the output voltage (n and δ) and those of the circuit (Δ and C_1/C_2).

It is possible to reduce the ratio C_1/C_2 only down to a certain value, since the smaller this ratio, the larger must E be for a given V_0. Ratio C_1/C_2 should be selected on the basis of a given value of V_0 and the maximum possible E, remembering that if E is raised very much, its supply circuit may become too complicated.

Thus, if the nominal values of V_0, $V_{max} = n_{max}V_0$ and δ_{max} are given, it is possible on the basis of the above considerations to select a value for C_1/C_2 and from (17) determine the largest possible value for Δ:

$$\Delta\leqslant\frac{C_2}{C_1}\frac{2\delta_{max}}{n_{max}} \tag{19}$$

An amplifier with a 100% negative feedback can be used for providing a gain which can be made arbitarily close to unity. The gain of such an amplifier is equal to

$$K = \frac{1}{1 + \frac{1}{K_0}}, \tag{20}$$

where K_0 is the gain with the feedback disconnected.

In order to make K approach unity, K_0 should be sufficiently large. Then we shall have approximately

$$K = 1 - \frac{1}{K_0}. \tag{21}$$

From (21) and the adopted assumption ($K = 1-\Delta$, where $\Delta << 1$), it is possible to consider that

$$K_0 = \frac{1}{\Delta} \tag{22}$$

and

$$K_0 > \frac{C_1}{C_2} \frac{n_{max}}{2\delta_{max}} \tag{23}$$

Expression (23) determined the gain of the amplifier with a disconnected feedback which would make the output voltage meet the required value.

The above relations have been obtained with the assumption that capacitor C_2 is not shunted by a resistance. In fact, however, capacitor C_2 is shunted by the input resistance of the amplifier and the load resistance of the circuit under consideration. This shunting effect decreases a little the voltage across the capacitor at each step. The circuit parameters should be selected so as to make the error due to the deviation of the gain from unity and the discharge of the capacitor small. Hence, the effect of the resistance shunting capacitor C_2 on the output voltage can be considered separately, assuming that the gain of the amplifier is exactly equal to unity.

2. The effect of capacitor C_2 discharge. The shunting of capacitor C_2 by a resistance makes the otherwise stable voltage of each step vary according to the law

$$V = V_i e^{-\frac{t}{\Theta}}, \tag{24}$$

where V_i is the initial step voltage; $\Theta = C_2R$; R = the resistance which shunts the capacitor C_2. At the end of each period, the voltage is •

$$V_\kappa = V_i e^{-\frac{T}{\Theta}}. \tag{25}$$

Since $T << \Theta$ always holds, it is possible to consider that

$$V_\kappa = V_i \left(1 - \frac{T}{\Theta}\right) = V_i (1-a), \tag{26}$$

where

$$a = \frac{T}{\Theta}. \tag{27}$$

From (26) it is possible to write the following expressions for the voltage at the beginning of each step:

• With the assumption made at the beginning about the value of the impedances of the rectifiers and the voltage source E, the duration of the input pulses will not affect the output voltage.

At the beginning of the first step

$$V_1 = V_0;$$

at the beginning of the second step

$$V_2 = V_1(1-a) + V_0 = V_0(2-a)$$

and then, similarly,

$$V_3 = V_2(1-a) + V_0 = V_0(3-3a+a^2);$$
$$V_4 = V_3(1-a) + V_0 = V_0(4-6a+4a^2-a^3) \text{ etc.}$$

It can be shown that, at the beginning of the nth step, the voltage is equal to

$$V_n = \frac{V_0}{a}[1-(1-a)^n]. \tag{28}$$

The absolute error at the beginning of the nth step is

$$\Delta V_n = nV_0 - V_n,$$

and the relative error is

$$\delta_n = \frac{\Delta V_n}{nV_0} = 1 - \frac{1-(1-a)^n}{an}. \tag{29}$$

Since

$$(1-a)^n = 1 - an + \frac{n(n-1)}{2!}a^2 - \frac{n(n-1)(n-2)}{3!}a^3 + \ldots,$$

then

$$\delta_n = \frac{a(n-1)}{2!}\left[1 - \frac{(n-2)a}{3} + \frac{(n-2)(n-3)a^2}{12} - \ldots\right].$$

In practice, $\delta_n \ll 1$ always holds. Hence, all the terms in the square brackets of the last expression, beginning with the second term, are considerably smaller than unity. Taking into account that $n \gg 1$, we can write

$$\delta_n \simeq \frac{an}{2}, \tag{30}$$

or

$$\delta_n = \frac{nT}{2\theta} = \frac{n}{2\theta f}, \tag{30a}$$

where f is the repetition frequency of the E pulses.

It will be seen from expression (30a) that the smaller the pulse repetition frequency the larger the relative error of the output voltage. If the parameters of the circuit and the maximum permissible error are given, it is possible to determine the minimum permissible pulse repetition frequency:

$$f_{min} = \frac{n_{max}}{2\theta\delta_{max}}. \tag{31}$$

SUMMARY

The above relationships make a rational approach to the selection of the generator circuit parameters possible, and provide its operating frequency range.

In addition, conclusions can be drawn about the basic conditions of the practical application of the above circuit:

1. When a small individual error in the steps is required, their number n should be large, but the height of each step V_0 should be small.

2. In order to make the error due to the deviation of the gain from unity small, it is necessary to make $C_1 << C_2$ and hence, $E >> V_0$.

3. In order to obtain a high precision of the output voltage, it is necessary to obtain a correspondingly high precision and stability of the pulse E amplitude. A high stability of the pulse repetition frequency is not required. The source of E pulses must have a relatively low internal impedance; otherwise capacitor C_1 will not have enough time to recharge completely during the interval between pulses.

4. The "diode pump" circuit should only be used as a reference voltage source if the pulse repetition frequency is sufficiently high. Otherwise the error due to the discharge of capacitor C_2 in its load will be too large.

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IMPROVEMENTS IN OSCILLOSCOPE MPO-2

V. Yu. Chudnovskii

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The eight-loop oscilloscope, type MPO-2, which is widely used in various experiments, has good characteristics. The experience of using the MPO-2 oscilloscope over a period of many years has, however, revealed certain constructional defects.

The oscilloscope lacks a device for stopping the mirror drum in a required position. This defect is especially noticeable when the oscilloscope operates at recording speeds of 1-100 mm/sec, since at these speeds the slow rotation of the mirror drum does not provide scanning, but impedes the observation of the vibrator beams on the screen. When low film propulsion speeds are used, the mirror drum occasionally stops in a position which does not provide a reflection of the vibrator beams on the screen, thus stopping any visual observation of the recording until the end of the filming.

In order to eliminate this defect, the author of this article suggests the use of a device which provides the stopping when required of the mirror drum, by means of the scanning speed control knob in a position which reflects the vibrator beams onto the middle portion of the screen.

The schematic of the device is shown in Fig. 1. The protruding part of the mirror drum 1 axle carries a notched crown wheel 2 which has six notches around its circumference. By the side of the wheel is set a guiding bracket 3 in which slides a prismatic pawl 4, fixed to a rod 5 which slides freely in a hole in lever 6. The rod carries spring 7, which is slightly compressed by means of nut 8. The lever is fixed at the end of a toothed rack 9, which moves the induction regulator when the continuous scanning control knob 10 is rotated. An index ball 11 is fitted under the knob. The knob has two fixed positions, one preceding the beginning of the scale (position I) and the other at the beginning of the scale (position II). Apart from these positions, the knob still controls continuously the speed of scanning.

In order to stop the mirror drum the knob should be placed in position I. Then lever 6, having been displaced, together with the toothed rack 9, into the extreme left-hand-side position, will through spring 7 lightly press pawl 4 against the edge of the notched crown wheel. Under the pressure of the spring, the pawl engages one of the notches and stops the mirror drum. In order to start the mirror drum, the knob should be rotated clockwise from position I. The mirror drum can be started with the motor running at any speed. It can be stopped by means of this device at film propulsion speeds up to 500 mm/sec. At higher speeds the knob should be turned

* See English translation.

to position I only with the oscilloscope motor switched off, in order to avoid the crown wheel knocking against the pawl.

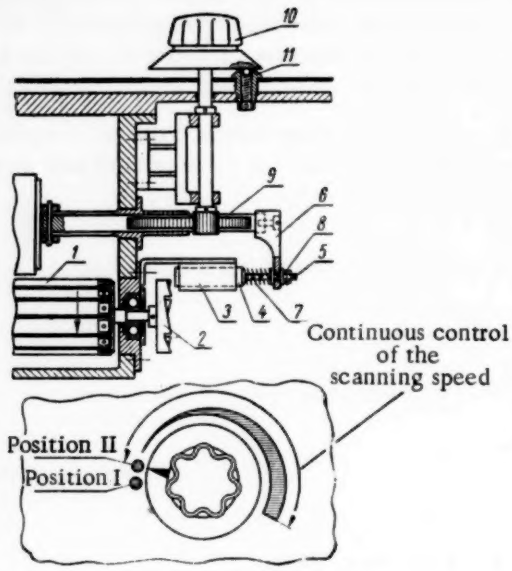

Fig. 1

In order to prevent the knob accidentally falling into position I at film speeds above 500 mm/sec, a second stop II is provided at the beginning of the continuous scanning speed control. In position II the gap between the pawl and the crown wheel notches amounts to 1 mm. When the knob is changed from position II to position I, the ball index prevents the knob stopping in an intermediate position, thus eliminating the possibility of incomplete engagement between the pawl and the crown wheel.

Another defect of the oscilloscope consists in the absence of a time marker for phenomena which are recorded at low film speeds, since the marker at 500 cps with which the oscilloscope is provided gives a recording which can be conveniently read only at film speeds exceeding 250 mm/sec.

This defect is compensated for to a considerable extent by incorporating in the oscilloscope a 50 cps time marker.

The 50 cps marks are recorded on the oscillogram by means of a normal vibrator type I or IV, fixed in the "marker" socket of the vibrator unit, to which the commercial frequency mains voltage is supplied through a building-out resistor r from the 25 v winding of the mains transformer by means of push button switch K (Fig. 2), which is mounted on the oscilloscope panel.

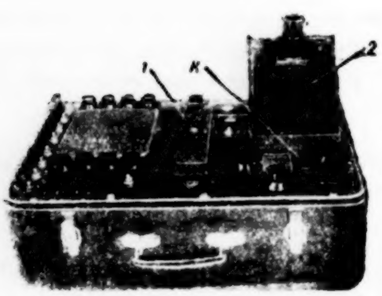

Fig. 2

The value of the building out-resistor r (6000 ohms) was selected so as to obtain two different marker amplitudes, one of 3 mm by means of vibrator type I and the other of 18 mm with vibrator type IV.

The 50 cps time marker is connected by pressing key switch K, which at the same time disconnects the vibrator normally used for marking. For convenience of operation, button K can be locked in the operating position. Such a marker can be successfully used (when the oscilloscope is fed from ac mains) for testing at film speeds of 25-500 mm/sec.

When an oscilloscope is supplied with such a marker, the insulation of button K and the supply circuit, with respect to the body of the instrument, should be tested at 2000 v.

When the oscilloscope MPO-2 is used under conditions of bright illumination, the gaps between the loading and receiving cassettes and the body of the film propelling device lead to the appearance of light patches on the film during stops.

The method of avoiding this effect recommended by the manufacturers, which consists of covering the cassettes with a piece of black cloth, is not sufficiently effective in practice and is inconvenient.

Light patches on the oscillogram taken at low film speeds (1-10 mm/sec) are sometimes produced by direct rays of light falling on the visual observation screen. These rays are reflected from the mirror drum into the optical system of the oscilloscope, reach the film, and produce light patches on it.

It is possible to eliminate the light patches completely by means of simple devices. One of them consists of a rectangular cover 1 made of sheet steel (Fig. 2) which covers both the loading and receiving cassettes. Its lower bent-out rim is covered with velvet so as to make the joint lightproof. The lever of the receiving cassette guillotine is placed under a swelling in the cover. Such a cover provides a reliable protection against light patches and is convenient in use, since it does not cover up the voltmeter, knobs, and dials placed near the cassettes as happens in the method recommended by the manufacturers.

The other device consists of shield 2 for the oscilloscope screen. In addition to protecting the film from light patches, this shield facilitates the placing of the beams on the screen and their observation during testing under conditions of bright exterior illumination.

SUMMARY

The above devices are simple to construct and can be made in any small laboratory. Their use makes testing much simpler and easier, and improves the quality of the oscillograms.

The experience gained in the use of oscilloscopes equipped with these devices during two years under laboratory and field conditions for investigating the operation of dredging machines points to the advisability of supplying MPO-2 oscilloscopes with such devices in the manufacturing stage.

HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS

CERTAIN INSTANCES OF THE USE OF ELECTRONIC PULSE COUNTERS IN MEASUREMENT TECHNIQUES

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Digital devices for measuring frequency and periods of vibration, voltages, time intervals, etc., are now being widely used in measurement techniques.

The design of these digital computers is based on the use of pulse counters and is described in literature [1, 2, 3].

In this article we examine some of the special instances of applying electronic pulse counters in measuring and monitoring equipments.

Frequency dividers with an adjustable division ratio. The conversion and generation of electrical oscillations is a sphere in which pulse counters can be effectively used. The use of electronic counters in conjunction with computer units for this purpose promotes still further the automation of measurements and the production of automatic measuring devices.

Frequency dividers, not only with a division ratio independent of frequency, but also dividers which have an adjustable ratio, can be made on the basis of pulse counters.

An advantage of these counters also consists in the possibility of adjusting the division ratio in decade steps, which makes them very convenient to use.

Dividers with an adjustable ratio can be designed in two ways.

One of them consists in varying the type and number of feedback circuits in a binary chain circuit, thus changing the conversion ratio of the circuit, i.e., changing the division ratio. A divider constructed on this basis will, however, be imperfect, with large conversion factors since many switching feedback circuits have to be used, thus making the circuit very unstable. Such circuits have not, therefore, been widely adopted.

The other method is based on the possibility of converting n series-connected binary cells by means of a single pulse to a condition corresponding to any number of stored pulses smaller than 2^n. This is attained by virtue of the fact that the conversion pulse only triggers the cells which constitute the given number m. If a circuit which is storing number m is fed with a series of pulses, it can be returned to its initial condition only when $2^n - m$ are received. Thus, the division factor of the circuit is made equal to $2^n - m$. If, during the interval between the $(2^n - m)$th and the subsequent pulse, the circuit is again switched to position m by means of a conversion pulse, the circuit will in practice become a conversion system with a factor of $2^n - m$. By varying number m from zero to $2^n - 1$, it is possible to adjust the conversion factor of the circuit, i.e., the division factor between 2^n and unity.

The block schematic of a division circuit with an adjustable factor is shown in Fig. 1.

The input signal, which is to be divided, is fed to the shaping device No. 1, which produces pulses of determined constant parameters with a repetition frequency equal to the frequency of the input signal. The shaped pulses are fed to the chain of series-connected binary cells.

Let us now examine the operation of the circuit from the instant when the chain has been switched to a position corresponding to number m. The following pulse will then transfer the circuit to condition $m + 1$. The

counting will continue until the $(2^n - m)$th pulse is received, which returns the circuit to a condition corresponding to 0. The voltage drop signal of the last cell is transformed by means of shaping device No. 2 into a conversion pulse which establishes, by means of the distributing device, number m on the corresponding cells. This process is repeated periodically.

In addition to the division coefficient, another important parameter of the divider is its speed of operation, which is determined by the maximum division speed and the resolution time. The latter is determined in the same manner as in the case of pulse counters.

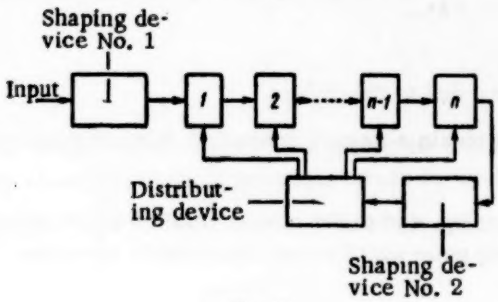

Fig. 1

Both of the above parameters do not numerically coincide with similar parameters of a conversion circuit on whose basis the divider is constructed: they are always worse for the divider, since the conversion pulse is considerably delayed with respect to the input pulse. The delay consists of the sum of the delays in the conversion cell or decade chain, and the shaping device. For a correct operation of the divider, it is necessary to stop transmitting pulses to the conversion circuit while the stable state is being attained, thus decreasing the divider's speed of operation.

In the case of a binary counting circuit, which consists of cells with a resolution time τ_p, the delay time is equal to $\Delta\tau n$, where $\Delta\tau$ is the delay time of one cell.

Figure 2 shows diagrams illustrating the time relations in the divider. Diagram 1 represents conventionally the $(2^n - m)$th and $(2^n - m + 1)$th pulses. Diagram 2 represents the voltage jump in the last cell of the conversion circuit, a jump from which the conversion pulse is formed (Diagram 3) and fed to the distributing device and the conversion circuit. The conversion pulse is artificially delayed with respect to the jump from which it is formed by a time τ_p, and pulse $(2^n - m + 1)$ can be fed to the circuit only when the interval τ_p has elapsed after the conversion pulse. The delay in the conversion pulse and the minimum time interval τ_p between the conversion pulse and pulse $(2^n - m + 1)$ are due to the fact that the conversion circuit, after receiving a pulse, has a finite operation time which is approximately equal to the resolution time τ_p. It will be immediately seen from the diagram that the resolution time of the divider is

$$\tau_{p\partial} \geqslant \Delta\tau n + 2\tau_p. \qquad (1)$$

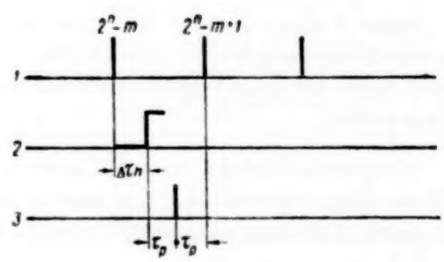

Fig. 2

The maximum division speed approaches the reciprocal of $\tau_{p\partial}$. It is evident that, in order to design high-speed dividers, it is necessary to use conversion cells and decades with a small delay and resolution time.

On the basis of the above divider, it is possible to design circuits for the conversion and generation of electrical oscillations.

Generation of delayed pulses. One of the applications of pulse counters involves the production of pulses with a variable delay.

The main advantages of such circuits consist in the possibility of controlling the delay over a wide range and in the high precision and stability of the delay (as the result of using a quartz crystal generator).

The principle involved in generating delayed pulses consists in selecting from their periodic sequence (reference sequence) two pulses which are separated from each other by M discrete periods of the reference sequence.

Figure 3 shows a block schematic of a device of that kind. The reference sinusoidal or pulse signal of frequency f_0 is fed to the input of shaping device 1 which produces pulses with required parameters. The pulses thus formed are fed to the normally blocked selector 2, controlled by trigger 5, which has a separate triggering through two inputs. The selector is made operative by a pulse at the left-hand-side trigger input or by pressing the but-

ton switch of the single pulse generator 4, or by means of an external starting pulse fed to input II. The shaping device 7 serves to normalize the shape of this pulse. The reference sequence pulses which pass through the selector are fed to the input of decade divider 3 of the type described above. The first pulse at the selector input is shaped in the shaping device 6, and used as a reference pulse. When the divider has counted the set number of pulses K, a pulse is fed from the output of divider 3 to the right-hand-side input of trigger 5 and returns it to the initial blocked position. Moreover, the feeding of pulses to the input of this divider is thus discontinued.

Thus, the pulse at the divider output will be separated from the reference pulse by a time interval of

$$\tau_d = \frac{1}{f_0}(K-1)+\Delta\tau_\partial. \tag{2}$$

where K is the ratio of the frequency divider; $\Delta\tau_\partial$ is the error due to the divider.

By varying K between unity and K_{max}, it is possible to obtain a stepped controlled delay of pulses at output II with respect to the pulses at output I.

It will be easily seen that the delay will not be equal to τ_d, due to the random relation of the reference sequence phase and the instant of the reception of the starting pulse which makes the selector operative. The value of the delay can obviously be represented in the form

$$\tau_d' = \frac{1}{f_0}\left(K-\frac{1}{2}\right)+\Delta\tau_\partial \pm \frac{1}{2f_0}. \tag{3}$$

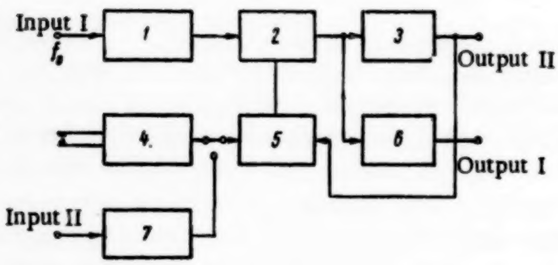

Fig. 3

With a sufficiently large division factor K, it is possible to neglect $\Delta\tau_\partial$ and $\Delta\tau_\partial \pm 1/2f_0$.

In this case (2) and (3) assume the form

$$\tau_d = \frac{1}{f_0}(K-1), \tag{2'}$$

$$\tau_d' = \frac{1}{f_0}\left(K-\frac{1}{2}\right). \tag{3'}$$

Thus, an essential defect of the above delayed pulse generating circuit is the low accuracy of the time delays due to the presence of error $\Delta\tau_\partial$ and the absence of a rigid synchronization between the output pulses.

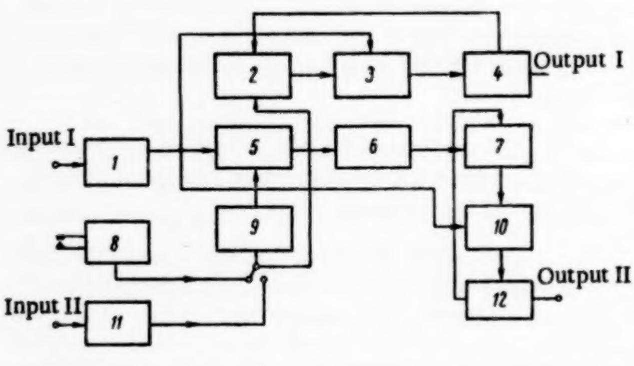

Fig. 4. Shaping device No. 1; 2) selector trigger No. 2; 3) selector No. 2; 4) shaping device No. 2; 5) selector No. 1; 6) frequency divider; 7) trigger selector No. 3; 8) single pulse generator; 9) selector trigger No. 1; 10) selector No. 3; 11) shaping device No. 4; 12) shaping device No. 3.

Figure 4 shows a circuit free from the above defects which, contrary to the circuit in Fig. 3, has additional stages for selecting the reference and output delayed pulses.

The selection of the reference pulse is carried out in the following manner. The starting pulse triggers selector 3 simultaneously with selector 5.

The first pulse of the reference sequence which is then received will pass through selector 3 and be fed to the output shaping device 4. The output reference pulse is fed to the second input of the selector trigger 2 after a certain delay, and triggers the above selector. Selector 3 is thus blocked.

Thus, the selection and shaping of the delayed pulse is attained by means of the selector trigger 7, selector 10, and the output shaping device 12.

Owing to the presence of the selection stages,the value of delay can be represented by the following expressions:

for a delay between the reference and delayed pulses

$$\tau_d = \frac{1}{f_0} K, \tag{4}$$

for a delay between the starting and delayed pulses

$$\tau'_d = \frac{1}{f_0}\left(K + \frac{1}{2}\right) \pm \frac{1}{2f_0}. \qquad (5$$

The above circuit can serve as a basis for designing a precision delayed generator. In this instance the oscillations of a quartz crystal generator should be used as the reference train.

Figures 5 and 6 show the diagrams of the time relationships for circuits of Figs. 3 and 4.

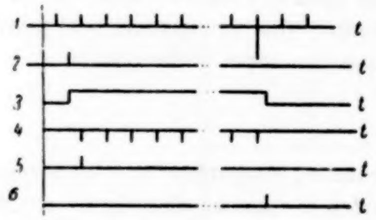

Fig. 5. 1) Reference sequence pulses; 2) starting pulse; 3) selector trigger output pulse; 4) selector output pulses (a pulse train); 5) reference pulse; 6) delayed pulse.

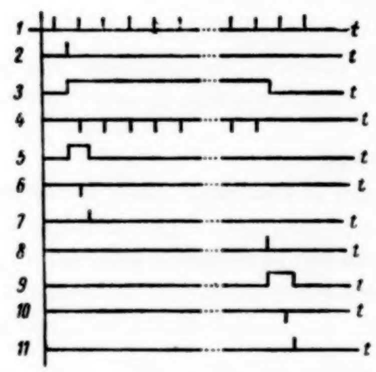

Fig. 6. 1) Reference sequence pulses; 2) starting pulse; 3) selector trigger No. 1 output pulse; 4) selector No. 1 output pulses (a pulse train); 5) selector trigger No. 2 pulse; 6) reference pulse; 7) output I feedback pulse; 8) frequency divider output pulse; 9) selector trigger No. 3 output pulse; 10) delayed pulse; 11) output II feedback pulse.

Generation of pulse trains. In experimental investigations and in tuning of radio equipment, it is often necessary to provide trains of evenly spaced pulses with an accurately known number of pulses per train, and a definite train repetition frequency. For this purpose the above delayed pulse generating circuits can be used with advantage. In fact, pulses at the output of selector 2 (Fig. 3) represent a train consisting of K pulses with a repetition interval equal to the period of the reference pulse sequence, and with a train repetition period equal to the repetition period of the start-stop pulses. If the shaping device 6 is set to deal not only with the first pulse of a train,but with the shaping of all the pulses in a train, output I will provide a sequence of pulse trains with the number of pulses in each train determined by the division factor of the divider.

An important property of the above circuit consists in the fact that the number of pulses in each train and their repetition frequency are completely independent from each other, which,in a number of cases, is of considerable interest.

Generation of rectangular adjustable duration pulses. The delayed pulse generating circuits can also be used for generating rectangular pulses with an adjustable and accurately set duration. For this purpose, it is necessary to include a shaping trigger with an output stage in the circuit (Figs. 3 and 4).

A simplified block schematic of a rectangular pulse generator is shown in Fig. 7. The reference (output I) and the delayed (output II) pulses are fed to the inputs of the shaping trigger. In its initial condition, shaping trigger 2 cannot be started by the reference pulse fed from output I. After having been tripped by this pulse, the trigger is returned to its initial condition by the delayed pulse which is fed from output II. It will be seen from the above that it is possible to obtain at the output of the trigger rectangular pulses of both polarities, whose duration is equal to the delay between the pulses of the delayed pulse generator. In order to match it to its load, the circuit is provided with an output stage 3.

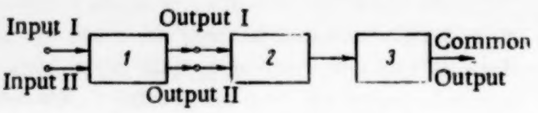

Fig. 7. 1) Delayed pulse generator; 2) shaping trigger; 3) output stage

When a divider consisting of six decades is used, and the reference repetition frequency is 1Mc, it is possible to provide pulse generation in the range between 2-3 and 999999 μsec in steps of 1 μsec.

In the above generating circuits of delayed and rectangular pulses and pulse trains, the operational conditions of the divider counters differ from those obtaining under division conditions. The difference consists in the fact that in the above circuits the time interval between the routine operation cycle of the divider is always larger than under division conditions. This provides a full utilization of the high-speed capacity of the divider circuit and the possibility of working with pulse sequences whose repetition frequency approaches the maximum counting speed of the circuit.

It was already mentioned that when the above circuits are triggered by external pulses which are not coherent with respect to the pulses of the reference sequence, the instant at which the reference pulse appears is dispersed with respect to the starting pulse within the limits of one pulse repetition period of the reference sequence. In many practical cases, such a characteristic is inadmissible. In order to eliminate this effect, a shock-excited circuit should be used in the reference sequence generating circuit. This arrangement will provide a rigid coupling with respect to time of the starting pulses and the pulses at the output of the circuit.

SUMMARY

Conversion circuits can be used for designing monitoring and measuring equipment for most diverse applications. Such instruments, side by side with digital devices, are intended to measure directly various physical quantities, and provide, in conjunction with units used in computer equipment, the possibility not only of producing complex measuring equipment, but also of processing data obtained in measuring several parameters and providing results which are of direct interest to the operator.

In order to raise the reliability and efficiency of such instruments and to decrease their over-all dimensions and weight, it is advisable in the near future to transistorize these sets.

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COMPENSATION OF DIODE NONLINEARITY

A. É. Vishnyakov

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 45-46, May, 1960

When nonlinear resistors are used for detection and rectification by virtue of their unidirectional conductivity (henceforth, we shall call them diodes), amplitude distortions arise due to the nonlinear relation of the dc

* See English translation.

current flowing through the diode to the applied voltage. Therefore, in measurement techniques and electronics, methods compensating the nonlinearity of the diodes [1-4] are widely used.

The most widespread method of compensation consists of:

1. connecting in series with the diode large building-out resistances;
2. an artificial increase of the current flowing through the diode;
3. introducing a dc source which displaces the volt-ampere characteristic of the diode to its linear portion.

The compensation method suggested in this article consists in the use of a potential divider which is made up of nonlinear resistances and provides a linear relation of the rectified voltage (current) to the alternating voltage for a considerably lower value of the ac voltage than the previously mentioned methods. Moreover, this method provides at the same time an automatic temperature compensation.

Let us now examine the voltage divider (Fig. 1) consisting of linear resistors R_1 and R_2 and two diodes D_1 and D_2. The load resistance R_l is connected in parallel with R_1 and D_1.

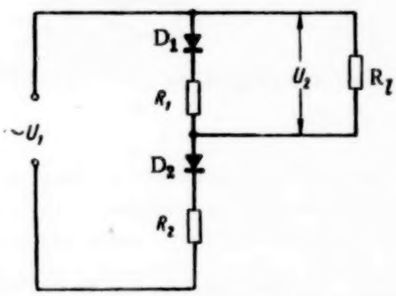

Fig. 1

The values of the forward (R_f) and reversed (R_r) resistances of some of the diodes are given in the table.

In order to obtain rectification in the circuit of Fig. 1, it is necessary to have

$$R_l \ll R_r + R_2. \tag{1}$$

In practice, this inequality always holds, since the values of the reversed resistances are large (see table, column 3).

On the other hand, let us assume that

$$R_l \gg R_f + R_1. \tag{2}$$

For $R_l = 10R_f$ inequality (1) holds for all types of diodes (see table, column 4). Hence, the load in the circuit of Fig. 1 can be selected so that

$$R_1 + R_f \ll R_l \ll R_r + R_2. \tag{3}$$

The left-hand side of (3) makes it possible to neglect henceforth, in considering the circuit in Fig. 1, the shunting of the diode by a load for the forward half of the wave. The right-hand side of (3) makes it possible to neglect the effect of the reversed half-wave of the rectified voltage. Let us examine the circuit of Fig. 1 on the basis that (3) is fulfilled.

Let an alternating voltage U_1 be applied to the terminals. Let us find U_2. We assume that diodes D_1 and D_2 have a similar relation of the applied voltage to the current:

$$I = f(U_D),$$

where I is the direct current flowing through the diode; U_D is the direct voltage applied to it.

The following relationships hold for the instantaneous values of the current and voltages:

$$I = f(U_D) = \frac{U_D}{R_f}, \tag{4}$$

where R_f is the forward resistance of the diode which depends on U_D;

$$I = \frac{U_1}{R_1 + R_2 + 2R_f}. \tag{5}$$

$$U_2 = IR_D + IR_1. \tag{6}$$

Let us find R_f from (5) and substitute it in (6). At the same time, let us replace I by $f(U_D)$. Thus, we have

$$U_2=f(U_D)\left[\frac{U_1}{2f(U_D)}+\frac{R_1-R_2}{2}\right]. \tag{7}$$

Equation (7) shows that U_2 in a general case is a nonlinear function of U_1.

Table 1.

Diodes	$R_{f.min}$	R_r	R_r/R_l for $R_l = 10R_{f.min}$
1	2	3	4
Germanium	< 10	10^5	10^3
Silicon	10	10^6	10^4
Tube	10^2	10^{10}	10^7

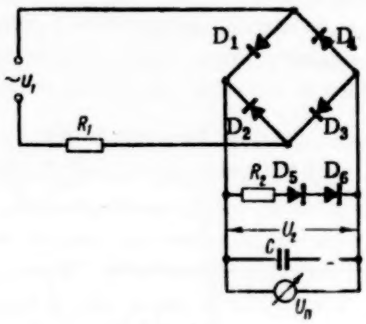

Fig. 2

Let us assume that $R_1 = R_2$; then

$$U_2 = U_1/2 \tag{8}$$

The reversed half-wave hardly affects U_2, since formula (3) holds, and therefore, U_2 can be considered as the rectified voltage.

Thus, in order to obtain a linear relationship between the rectified voltage U_2 and the applied voltage U_1, it is necessary to fulfill the inequality (3), make R_1 equal R_2, and select diodes with identical characteristics.

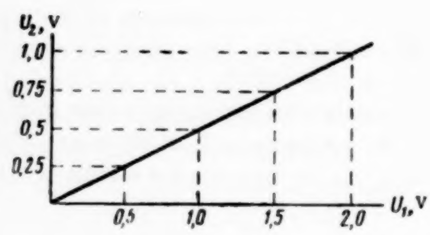

Fig. 3

A full-wave rectifying circuit (Fig. 2) can be designed on similar lines. The linearity conditions are the same as for the circuit in Fig. 3.

It is peculiar to the circuits in Figs. 1 and 2 that any changes in the values of R_f (due to time, temperature, etc.) do not affect the relation between the rectified voltage and the applied voltage, providing they occur similarly and simultaneously in both diodes. This conclusion follows from (8), since U_2 does not depend on R_f. Thus, in the circuits of Figs. 1 and 2, an automatic temperature compensation for the forward half-wave is attained.

Figure 3 shows an experimentally attained relation of the rectified voltage U_2 to the alternating voltage U_1 for the circuit in Fig. 2. The rectifier of Fig. 2 consisted of DGTs-27 diodes, $R_1 = R_2 = 2000$ ohms and $C = 5 \mu f$.

Generator ZG-10 was used as the source of the alternating voltage, and measurements were made by means of set IP-1 with voltmeter M-193.

The rectifier (Fig. 2) was placed in a thermostat. The temperature error of the circuit was reduced in the range of -30 to +30°C to 1/10 of its value with a normal full-wave rectifying circuit.

SUMMARY

The above circuit can be used for ac milliammeters and millivoltmeters, for linear detection in radio receivers, etc.

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CHECKING CRYSTAL OSCILLATORS

V. P. Lobodin

Translated from Izmeritel'naya Tekhnika, No. 5, p. 46, May, 1960

In the work of inspection agencies which possess a reference frequency of 1000 cps (normally used in radio), it is often necessary to use quartz crystal oscillators with frequencies of 100 kc, 1 Mc, and 10 Mc. In this case testing is considerably simplified when the frequency of the reference oscillators is divided by means of the calibrating oscillator frequency dividers types KG-A, KG-B, and KG-V.

The reference generator frequency 10 Mc is divided by set KG-V down to 1 Mc. The thus obtained frequency of 1 Mc is divided by set KG-B down to 100 kc. Finally, the frequency of 100 kc is divided by set KG-A down to 10 and 1 kc. The latter frequency is checked against a reference frequency of 1000 cps.

The frequencies under test of 1 Mc and 100 kc are fed to dividers of set KG-B and KG-A for division down to 10 and 1 kc. In order to be able to apply the tested frequencies to each of the three sets KG-A, KG-B, and KG-V, it is necessary to mount sockets and double-pole double-throw switches (tumbler switches), in all of them; and in sets KG-B and KG-V, in addition to the above, a 100 $\mu\mu f$ capacitor.

The switches are connected in the circuit in such a manner that in one position the circuit remains without alteration, and in the other position, the anode circuit of the crystal oscillator is disconnected as, simultaneously, a signal from the socket is fed to the corresponding frequency divider. In set KG-V the signal is fed through the additional capacitor to the third grid of tube T_{32}; in set KG-B the signal is also fed through an additional capacitor to the third grid of tube T_{46}, and in set KG-A the signal is fed through capacitor C-113 to the grid of the right-hand-side triode of tube T_{107}.

RADIATION MEASUREMENTS

MEASUREMENT OF GAMMA AND BETA RADIATION DOSES BY MEANS OF THIMBLE IONIZATION CHAMBERS

V. V. Smirnov

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 47-50, May, 1960

The determination of an absorbed dose of gamma radiations in any substance is based on measuring the ionization produced by secondary electrons in a small cavity filled with gas inside the medium under test [1]. Tissue-equivalent substances are especially important for dosimetry.

The relation between the radiation dose D and the ionization in the cavity I is given by the Bragg-Gray expression

$$D = Is\epsilon, \tag{1}$$

where $\underline{s}$ is the effective stopping power of the solid substance and the gas, which fills the cavity; ϵ is the work of ionization [2].

In practice, the gamma radiation doses are measured by means of thimble or wall radiation chambers, in which the absorption of the gamma rays and the formation of secondary electrons is restricted almost entirely to walls, which surround the ionization volume of the chamber. The thickness of the walls must be sufficient to produce a balance between the gamma radiations and the secondary electrons thus produced.

Relationship (1) holds if the following basic conditions are fulfilled: the ionization volume of the chamber is sufficiently small, so that the secondary electrons lose in it only an insignificant part of their energy; the atomic numbers of the walls and the gas differ little from each other; at all the points of the ionization chamber, the radiation field can be considered uniform.

A correct interpretation of the processes inside a thimble ionization chamber is only possible if the energy spectra and angular distribution of the secondary electrons which have been knocked out of the chamber walls by the incident gamma radiations are known in detail.

We have studied systematically the spectra and angular distribution of the secondary electrons, knocked out by gamma rays of Cs^{137} and Co^{60} from targets simulating the walls of an ionization chamber [3].

Investigations were carried out by means of a magnetic spectrometer whose construction provided spectra of electrons in angular intervals of 0 to 180°. We used targets made of graphite, plexiglas, aluminum, copper, cadmium, and lead. The thickness of the targets for the series of measurements was chosen to equal the maximum path of electrons which are formed when Co^{60} gamma rays are absorbed in the substance.

Figures 1 and 2 show the electron spectra which correspond to equal values of the solid angle, and were knocked out from a plexiglas target by Cs^{137} and Co^{60} gamma rays at various incident angles. It will be seen that the spectra of the electrons knocked out in the direction of the incident gamma quanta (angle 0°) have a "peak" which corresponds to the recoil electrons of maximum energy. As the angles are increased, there is a noticeable drop in the intensity of electron radiation and a blurring of the fringes due to slow electrons.

The angular distribution of electrons knocked out of the graphite, plexiglas, and lead targets by Cs^{137} and Co^{60} gamma rays are shown in Figs. 3 and 4.

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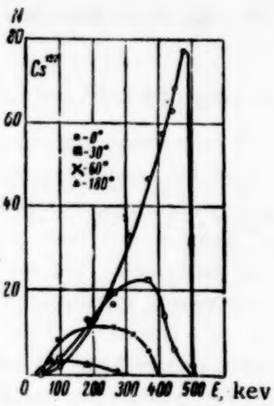


Fig. 1

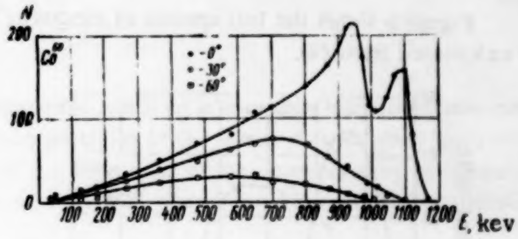


Fig. 2

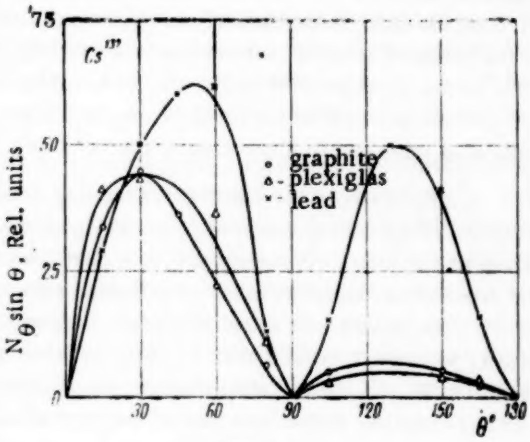


Fig. 3

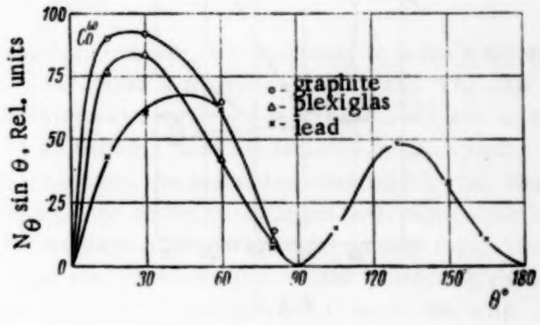


Fig. 4

The values of the angle are plotted along the x-axis,and the number of electrons moving in the ring between angles Θ and $\Theta + d\Theta$ along the y-axis; it is equal to $2\pi N_\Theta \sin\Theta\, d\Theta$, where N_Θ is the number of electrons at angles Θ within the limits of a definite solid angle. The curves of angular distribution have been drawn on the same scale, and the areas bounded by them characterize the full number of secondary electrons which are being produced by the targets under the action of gamma rays. It will be seen from the graphs that the electron escape for substances with small atomic numbers has a clearly expressed "forward" pattern in the direction of the gamma quanta movement. The intensity of electron radiation in the direction of angles of 90-180° from graphite and plexiglas targets, under the action of Co^{60} gamma rays, is very small.

For substances with a large Z (lead) the angular distribution of secondary electrons approaches an isotropic one, which corresponds to a sine wave; there is also a large number of electrons which move "backwards". It should be noted that the appearance of secondary electrons at angles of 90-180° is due to the scattering in the target at large angles of electrons which have been knocked out in the "forward" direction.

The full number of electrons N_n knocked out of the target by the gamma rays is determined by the expression

$$N_n = \int_0^{E_m} \int_0^{\pi} 2\pi \sin\Theta N(E, \Theta)\, dE\, d\Theta, \tag{2}$$

where N (E, Θ) is the experimentally established number of electrons knocked out by gamma rays in the energy interval of E to E + dE and in the direction between the angles Θ and Θ + dΘ. E_m is the maximum energy of secondary electrons.

Figure 5 shows the full spectra of electrons knocked out of a plexiglas target by Cs^{137} and Co^{60} gamma rays as calculated from (2).

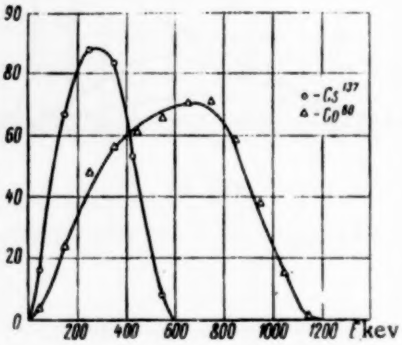


Fig. 5

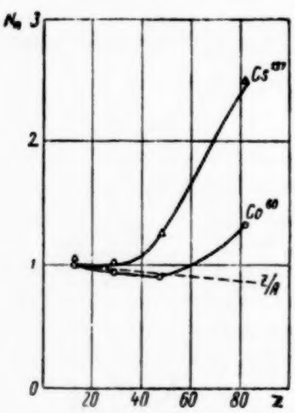


Fig. 6

Figure 6 shows the relative variation of the full number of secondary electrons, knocked out of targets by Cs^{137} and Co^{60} gamma rays, with respect to the atomic number of the targets. The formation of electrons due to a noncoherent scattering of gamma rays is proportional to Z/ A (the ratio of the atomic number Z to the atomic weight A) of the substance. It will be seen from the graphs that, for Co^{60} gamma radiations, the full number of produced secondary electrons right up to Z ≈ 50 follows the ratio Z/ A. For Cs^{137} gamma radiations, this relation holds only up to Z ≈ 30. The rise in the number of secondary electrons for large values of Z is due to the appearance of photoelectrons. With Cs^{137} radiations, the process of photoelectric absorption of the gamma radiations in the range of large Z numbers plays a decisive part; thus, in the Z range of 48 to 82, the cross section of this process amounts to 0.15-0.4 of the total cross section of gamma ray absorption in the substance.

On the basis of the spectra and the angular distribution of secondary electrons thus obtained, the relative and absolute efficiency was calculated for flat-slot ionization chambers made of different materials [4, 5]. The values thus found are in good agreement with experimental results obtained by several investigators [6, 7] who studied the relation of ionization in a chamber to the atomic number of the wall materials and the energy of gamma rays.

There are many types of thimble ionization chambers adapted for measuring beta and gamma radiations from sources of different sizes and constructions. In measuring the doses of gamma radiations, it is necessary to take into account, in addition to the ionization produced by the electrons knocked out of the walls of the chamber by gamma rays, also the electrons scattered from the opposite walls, and the fact that they may cross the measuring volume and produce additional ionization. Experiments have shown that in chambers made of light materials the additional ionization produced by the rescattered electrons amounts to 5% for electrons with energies of 700 kev. Since the basic ionization is produced by the secondary electrons knocked out of the front wall of the chamber by gamma rays, the geometrical surface which corresponds to the measured radiation dose should be referred to the internal area of the front wall. In order to determine the value of ionization produced by the secondary electrons per unit volume of the chamber, it is necessary to know the volume of the space from which the ions are gathered. In practice, the ionization volume of the chamber is small and cannot be determined from purely geometrical data with sufficient accuracy. A precise determination of the ionization volume of the chamber can be carried out by calibrating it against a reference source of gamma radiations. If the value of the dose produced by the source in a given point of the chamber amounts to P, and the measured ionization current is I, we have

$$I = P \cdot 2.08 \cdot 10^9 eV, \quad (3)$$

where V is the ionization volume of the chamber; e is the charge of an electron.

Solving (3) with respect to V and expressing the dose in terms of the activity of the source A, and distance R to the front wall of the chamber, we find

$$V = \frac{IR^2}{\Gamma A \cdot 2.08 \cdot 10^9 e}, \tag{4}$$

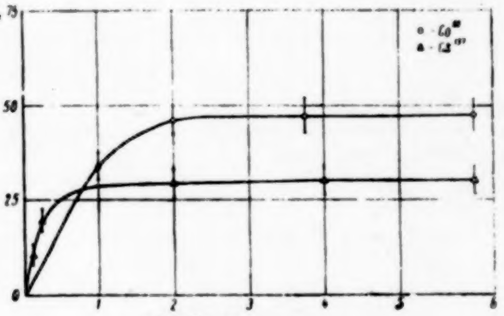
where Γ is the gamma constant of the isotopes [8].

For beta radiation dosimetry, the front wall of the chamber is made of a very thin material tissue-equivalent to air, so as to reduce to a minimum the absorption of beta particles in it. When it is required to determine the beta radiation dose at a certain depth, the thickness of the front wall of the chamber may be correspondingly increased. The beta radiation dose determined by means of a thimble chamber corresponds geometrically to the center of the ionization volume of the chamber.

The chamber can be calibrated by means of a reference gamma radiation source, and the thin wall of the chamber replaced by a wall of an equilibrium thickness. The calibration accuracy will increase with a rising similarity between the energy spectra and the distribution in space of beta particles of the source and the secondary electrons produced by the gamma rays in the wall of the chamber. Thus, for instance, in measuring the dose from sources Tl^{204} and Y^{91}, the chamber can be calibrated, respectively, with Cs^{137} and Co^{60} gamma rays. It seems to be advisable in calibrating to select for each source of beta radiations, according to its maximum beta spectrum energy, a gamma radiator of a corresponding energy. It should be noted that in calibrating beta dosimeters by means of reference gamma radiators, the values of the dose rate must be referred to different points. A dose of gamma radiations corresponds geometrically to the internal surface of the front wall of the chamber of an equilibrium thickness, and a dose of beta radiations corresponds to the center of the ionization volume of the chamber. The error due to this discrepancy will be substantial for chambers with a large ionization volume, and also if the source of gamma radiations is placed too near the chamber.

In measuring the dose rate from sources radiating beta and gamma rays, it is necessary to make a separate determination of the dose from each radiation. The chamber should have a detachable front wall. The dose due to purely gamma radiations is determined by means of a wall which has a sufficient thickness to achieve an equilibrium flow of secondary electrons, and for a full absorption of all the beta particles radiated by the source. When measuring the dose of beta radiations, a very thin wall or grid is used, and the ionization chamber receives both beta and gamma radiations. It should be noted that in this instance we do not measure the total dose, since, having removed the wall of equilibrium thickness, we thus alter the response of the chamber to gamma rays. This is due to the fact that, in reducing the thickness of the wall, we have also decreased the number of secondary electrons formed by gamma radiations. Since, in beta-ray dosimetry, the wall of the chamber is made very thin, the ionization in the chamber due to secondary electrons knocked out of the walls is also small.

In order to analyze and evaluate this phenomenon, we have used spectra and angular distributions of secondary electrons knocked out of plexiglas targets of various thicknesses by Cs^{137} and Co^{60} gamma rays. On the basis of the data thus obtained, we determined the variation of the full number of secondary electrons and their ionization action with respect to the thickness of the chamber wall. Fig. 7 shows characteristic curves of the variation of the number of secondary electrons knocked out of plexiglas targets by Cs^{137} and Co^{60} gamma rays with respect to the thickness of the targets. Both curves are referred to the same number of gamma quanta and characterize the relative output of secondary electrons from plexiglas under the action of gamma rays. The curves representing the ionizing effect of secondary electrons bear the same relation to each other and have the same shape as the curves of Fig. 7. The variations of the response of ionization chambers to gamma radiations with a decreasing thickness of their walls should be taken into account when measuring the total dose of beta and gamma radiations.



Thickness, mm

Fig. 7

Moreover, with a thin front wall in the ionization chamber, secondary electrons knocked out of the source casing by the gamma rays and the air layer between the source and the chamber, will penetrate into the ioniza-

tion volume of the chamber. This circumstance leads to a degree of uncertainty in the thickness of the layer of the substance which serves as the front wall of the chamber when the dose of gamma radiations is measured.

SUMMARY

The above experimental investigations of secondary electrons produced in thick layers of substances, serve to obtain a deeper understanding of the essence of the processes which take place in gamma radiation detectors, and to arrive at several conclusions about their efficient use.

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APPLICATION OF RADIOACTIVE ISOTOPES FOR MEASURING THE MOISTURE CONTENT OF STEAM

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The urgent problem of modern thermotechnics (boiler and turbine construction) is the control of the humidity of steam. The existing methods of measuring humidity are unsatisfactory. The most widespread calorimetric method requires steam sampling, which is often difficult, and does not provide continuous control. The humidity measurements obtained by means of the capacitative method depend on the geometrical dimensions of the coagulating moisture drops.

The method of measuring the humidity of steam suggested in this article consists in determining the density of steam by the absorption of beta particles.

It is known that the absorption of beta particles, which are radiated by a radioactive isotope and transmitted through a d thick layer of a substance, is represented by an exponential law

$$I = I_0 e^{-\mu' \rho d}, \tag{1}$$

where $\mu' = \mu/\rho$ is the mass absorption coefficient; μ is the linear absorption coefficient; I_0 is the intensity of an electron beam before transmission through the layer of the substance; I is the intensity of the beam after transmission through the d thick layer; ρ is the density of the absorbent.

Thus, knowing I_0 and I, the mass absorption coefficient and the thickness of the absorbent, it is possible to determine the density of the absorbing substance—in this instance, of steam.

Having determined density ρ of humid steam, and using the thermodynamic relationship, we find the humidity of steam:

$$\varphi = \frac{\rho - \rho'}{\rho'}. \tag{2}$$

* See English translation.

where ρ' is the density of dry steam, determined in each particular case from the thermodynamic steam tables by the measured temperature and pressure.

In selecting the best type of radiation, we found a β-radiator the most suitable, since γ-radiations are absorbed weakly by steam and would provide a low sensitivity to density variations, and the use of α-radiations is difficult, owing to the small range of α-particles.

Of the β-radiation sources, we selected a radioisotope of sulfur (maximum energy of the β-spectrum $E_{max} = 0.167$ Mev).

Preliminary laboratory experiments were conducted with the object of selecting the activity of the source and counter, determining the optimum scattering between the isotope and the counter and finding the absorption coefficient.

The experiments were conducted on a test installation (Fig. 1) which provided variations of the activity of the source, of the absorption layer thickness, of the pressure and temperature of steam.

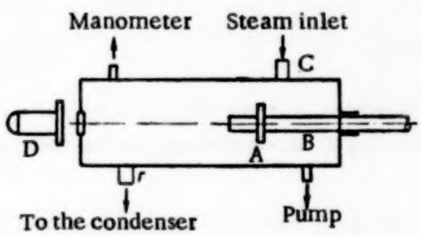

Fig. 1

Vessel A with the source of radiations was fixed to movable metal rod B. Reduced pressure was obtained by means of a prevacuum pump. The inlet and outlet of steam were provided by means of branch pipes C and E.

The counter D was located outside the test installation, since available electron counters could not work at temperatures higher than 50°C.

In the chamber of the installation, a window was made in the path of the electrons to the counter; it could be closed by an aluminum foil, which was protected from external pressure by an aluminum plate with numerous holes. The diameter of the window was equal to that of the butt end counter; a counter of the T-25 BFL type was found most suitable for the purpose.

Beta-radiating substances with a high boundary energy of electrons possess a smaller absorption coefficient and provide a smaller sensitivity. It should be noted that variations of density with humidity changes of 1% amount to $2.04 \cdot 10^{-3}$ kg $\cdot$ sec^2/ m^4. In order to be able to record this change with a sufficient accuracy, the absorption must be considerable. The use of very soft beta spectra, however, with a maximum energy smaller than 100 kev, is impossible, owing to the absorption of electrons in the counter window. In the case of the radioactive isotope of sulfur S^{35}, preparations of high specific activity can be obtained, thus providing an almost point source for measurements. All the basic measurements were made with the source S^{35}. We also attempted to use Ca^{45} as a source of radiations. The preparations of isotope Ca^{45}, however, have a low specific activity. The source of the required activity will therefore have a thick self-absorbing layer and will not produce the required effect. One of the difficulties was the development of a hermetically sealed source of radiation. The vessel shown in Fig. 2 was used as a source of radiations; it was made of a material with a small atomic number (aluminum) in order to reduce bremsstrahlung. The radioactive substance 1 was placed in a toroidal channel at the bottom of the vessel. Vessel 2 was hermetically sealed by a 10 μ thick teflon film 4 pressed against it by the diffusor lid 3. Such a construction prevents the steam touching the isotope and carrying away sulfur from the vessel. Radiometer B-2 was used as a recording device for making measurements during 3 min. It was established that the maximum sensitivity is reached for a distance between the source and the counter of 10-14 cm. At shorter distances there is not sufficient electron absorption to be recorded with the required accuracy. Larger distances exceed the maximum range of beta particles.

In order to determine the density of steam, it is necessary to know the mass absorption coefficient of electrons. There is no printed information on the absorption coefficient of electrons in steam. Data contained in tables of electron absorption in other substances cannot be used, since the mass absorption coefficient depends on the Z number of the absorbent and the configuration of the equipment. These considerations lead to an experimental determination of the value of μ' under laboratory conditions, measured on an installation which simulated the dimensions of the factory equipment. The determination of μ' was made for steam.

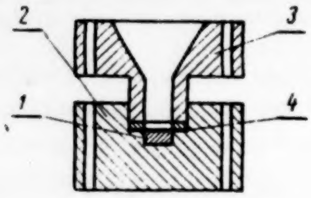

Fig. 2

It follows from (1) that

$$\mu' = -\frac{\ln \frac{I}{I_0}}{\rho d}; \tag{3}$$

μ' is found as the tangent of the slope angle of curves $\ln \frac{I}{I_0} = f(\rho d)$. Similarly, it was established that the mass absorption coefficient of electrons in superheated steam $\mu' = 197$ cm²/g.

Knowing the mass absorption coefficient and the distance between the source and the counter, it is possible to determine the density of humid steam ρ:

$$\rho = -\frac{\ln \frac{I}{I_0}}{d\mu'} \tag{4}$$

In order to check this method the Khar'kov Turbine Plant installed a device whose schematic is shown in Fig. 3. The equipment consists of a humidifier 1, a mixing section 2, an equalizing device 3 and a dead space 4.

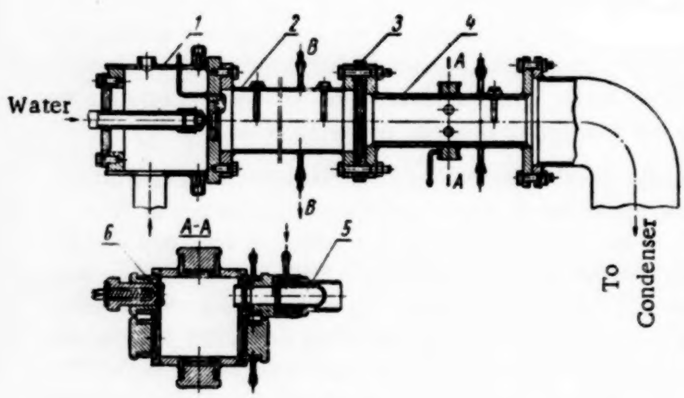

Fig. 3

Figure 3 shows the cross section of the measuring device (section A-A).

The dead space consists of a channel with a square cross section. One of its ends is joined to a butt end electron counter 5, the other to the vessel with the radioactive isotope 6. The counter is connected to the radiometer B-2. On either side of the dead space, two windows are cut perpendicularly to the flow of steam and provided with aluminum foil 10-15μ thick shutters fixed to a grate. The counter is protected from high temperatures by a flow of compressed air. Such a mutual position of the counter and the source makes it possible to determine the mean density of the steam flow across its section.

The equipment is supplied with dry, overheated steam from the factory steam pipes. The humidifier contains a calibrated jet through which water is injected in required amounts. In the mixer the water and steam are mixed so as to obtain the required amount of humidity.

This equipment provided humid steam moving at speeds of 5-200 m/sec with humidity values of 0-15%.

The steam pressure was varied from 1 to 0.1A_g and the temperature between 70 and 180°C. These steam parameters correspond to those obtained in the last stages of a turbine.

Measurements of μ' were carried out under factory conditions by the method described above. The value of the absorption coefficient in overheated steam $\mu' = 200$ cm²/g approached closely to the value obtained under laboratory conditions (the difference is within the limits of measurement errors).

We also determined the density of humid steam. The following sensitivity was obtained: when the density was changed by $2.04 \cdot 10^{-3}$ kg-wt $\cdot$ sec²/m⁴, the counting equipment readout varies by 190 pulses per minute.

The degree of humidity φ was determined from the measured values of μ' and ρ. Variation of humidity by 1% produces changes in the counting rate of 190 pulses per minute. When the humidity was changed from 0 to 10%, the counting rate varied between 4000 and 2000 pulses per minute.

Humidity values up to 6% with speeds of flow of 150 m/sec agree well with the values obtained by calculation, as shown in the table.

Density and humidity, determined by calculation		Density and humidity, determined by the absorption of β-particles	
ρ, kg-wt · sec²/m⁴	φ, %	ρ, kg-wt · sec²/m⁴	φ, %
0.0291	2	0.030	3
0.031	5	0.032	6

A further increase in the humidity and slowing down of the flow leads to the formation on the surface of the foil of a water film whose thickness, according to tentative calculations, varies between 20 and 60μ.

SUMMARY

The above tests show the theoretical possibility of measuring mean humidity of a steam flow without taking samples, and independently of the condition and size of moisture drops contained in the steam.

A TECHNIQUE OF TYPICAL CALIBRATION TABLES FOR HORIZONTAL CYLINDRICAL TANKS

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Compiling individual calibration tables for each tank size involves a large amount of labor-consuming calculations. It is, therefore, advisable for the plants manufacturing the tanks and the organizations engaged in calibrating typical tanks to compile typical calibration tables instead of individual ones, so that one table could be used for several tank sizes, and sometimes even for several tank types.

The essence of the suggested stepped-volume technique of compiling tables consists in drawing up normal calibration tables in centimeter intervals for flat-bottom tanks, or cylindrical parts of convex-bottom tanks, and then using these tables for various sizes of tanks.

The spacing of calibrations is determined by the required accuracy of the typical calibration tables: in tanks with a nominal capacity of 5 m^3 volume, calibrations are taken for each 15 liters; for tanks with a nominal capacity of 10 m^3, in 30 liter intervals; for tanks of 25 m^3 capacity, every 50 liters; for those of 50 m^3, every 100 liters; and for those of 75 m^3 capacity, every 150 liters.

The use of these volume intervals may produce an additional error in calibration tables: in tanks of 10 m^3 capacity not exceeding 0.2%, in those of 25, 50 and 75 m^3 capacity not exceeding 0.11% (in the operating instruction No. 149, additional errors up to 0.25% are allowed).

For the purpose of compiling typical calibration tables for horizontal cylindrical tanks with flat bottoms, all the tanks made at the plant are divided into groups each of which include tanks with the closest dimensions of diameters and lengths. Thus, the horizontal cylindrical tanks with flat bottoms of the 7-02-60 type, made according to the typical designs of the State Design Institute "Proektstal'konstruktsiya" are included in one group, and those of the 7-02-61 type in another, etc. The number of groups depends on the amount of tank types being manufactured.

When the tanks have been divided into groups, each one of them is assigned minimum and maximum diameter and length sizes* according to the actual dimensions of the manufactured tanks or from the design data, taking into consideration tolerances and deviations of actual sizes from the design values.

The subsequent compiling of calibration tables is carried out in the following manner:

1. On the basis of set minimum and maximum dimensions of a given tank group (according to their diameters and lengths), their capacity is calculated in the manner shown in Table 1.

2. Having taken for the basis of calculation the above-mentioned volume intervals and derived tank capacities, nominal tank capacities are selected for each diameter rounded off to the nearest 0.5 cm, in order to compile from them later typical calibration tables (in the manner shown in Table 2), assigning each table an ordinal number.

* The design diameters and lengths are determined by the usual methods .

3. For the selected groups of tanks and the adopted design nominal capacities, calibration tables in steps of one centimeter are then compiled by the generally adopted method. It is better to number typical calibration tables separately for each group of tanks, denoting it by means of a letter and indicating the ordinal number of the table and type of tank or its nominal capacity (for instance, T-1-10, which means typical table No. 1 for tanks of a nominal capacity of 10 m^3).

TABLE 1.

Capacities of Tanks Type 7-02-62

Length, cm	Mean weighted diameter, cm							
	218.1	218.2	218.3	218.4	218.5	218.6	. . .	219.6
	Tank capacities excluding internal equipment, liters							
281.5	10502	10511	10521	10531	10540	10550	. . .	10647
282.0	10520	10530	10540	10549	10559	10569	. . .	10666
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
289.5	10800	10810	10820	10830	10840	10850	. . .	10950

TABLE 2.

Ordinal number of the typical table	Diameter and the nominal capacity of the tank, liters
	D-218.0 cm
1	10510
2	10540
3	10570
etc	
11	10810
	D-218.5 cm
12	10520
13	10550
etc	
23	10850
	D-219.0 cm
24	10570
25	10600
etc	
35	10900
	D-219.5 cm
36	10635
37	10665
etc	
46	10935

4. In order to facilitate the selection of typical calibration tables under factory conditions, an auxiliary table is compiled in the manner shown in Table 3, with the indication of the ordinal number of the typical table intended for use with tanks of various dimensions manufactured at the plant. This table is compiled from Tables 1 and 2, so that the deviation of the nominal capacity does not exceed half the volume interval.

The numbers of the typical calibration table for each manufactured tank are determined from an auxiliary table and the actual dimensions of each tank.

Example. It is required to compile a typical calibration table for a group of tanks type 7-02-62. The nominal capacity of these tanks, according to their design data, is in the range of 10.7 to 11.6 m^3.

The maximum and minimum dimensions, taking into consideration possible deviations, are:

a) $D_{min} = 2181$ mm and $D_{max} = 2196$ mm;
b) $L_{min} = 2815$ mm and $L_{max} = 2895$ mm.

Taking the volume of the internal equipment of the tanks to be 15 liters, let us determine the capacity of the tanks for various diameters and lengths in the manner of Table 1.

For the group of tanks under consideration, which have capacities of 10.5 to 11 m^3, typical calibration tables are compiled in intervals of 30 liters (maximum deviation in the volume reading of ± 15 liters), separately for each selected nominal diameter of the tank, i.e., for D = 218.0, 218.5, 219.0 and 219.5 cm, and then the tables are numbered in the order of their sequence for the whole group of tanks in the manner shown in Table 2.

According to Table 1 and the table numbering shown in Table 2, a table is compiled for selecting typical calibration tables for dispatch to the customers (Table 3).

The cylindrical portion of horizontal tanks with convex bottoms is calibrated by the method outlined above for flat-bottomed tanks.

The length of the cylindrical part of the tanks with conical bottoms is taken to be the actual length of the cylinder plus the thickness of the shell's crimped rim up to the place where it is bent into a conical shape, and the length of the cylindrical portion of a tank with a spherical bottom, the actual length of the cylinder plus the cylindrical part of the bottom up to the place where it becomes spherical.

The conical bottoms are made by means of a special instrument which keeps the dimensions of the diameter and height of the cone constant. Deviations of these dimensions from the design values must not exceed the tolerances of ±7 mm in the diameter, and ±5 mm in the length.

Variations of 5 mm in the cone diameter will produce changes of 10-13 liters in the volume of the cone for a height of 345 mm. Variations of 5 mm in height of the cone or in rise of the sphere of convex bottom will produce changes in the volume amounting to 10-15 liters.

TABLE 3.

Length, cm	Mean weighted diameter, cm							
	218.1	218.2	218.3	218.4	218.5	218.6	. . .	219.6
	Numbers of the typical calibration tables							
281.5	1	2	12	12	13	13	. . .	36
282.0	1	2	13	13	13	14	. . .	37
282,5	2	2	13	14	14	14	. . .	38
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
289.5	11	11	22	22	23	23	. . .	46

In compiling typical tables, it is possible to take for the rise in spherical, and height in conical, bottoms the mean value of these quantities in the manufactured tanks, and for the diameter of the bottoms, the design diameter of the tanks.

The calibration of the convex bottoms (spherical, sphericooval and conical) is made according to the generally accepted rules of calibration. The sum of the capacity of cylindrical portion of the tanks and that of its two ends gives the total capacity for any given level of liquid in it.

LIQUID AND GAS FLOW MEASUREMENTS

EVALUATION OF THE ACCURACY OF MEASUREMENTS IN TESTING HYDRAULIC MACHINES

Yu. N. Solov'ev

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The errors obtained in testing hydraulic machines are not as yet estimated according to a uniform and recognized technique. The lack of generally recognized methods of evaluating the accuracy of these machines lowers considerably the value of any investigations, since it is impossible to compare the results thus obtained on different test instruments at different times; this makes it impossible to evaluate objectively the working quality of an instrument and the reliability of the results obtained.

This condition is due in the first place to the fact that the method of determining the error is based on a statistical analysis of test results and is not directly applicable in testing hydraulic machines, since it is often impossible to reproduce all the conditions which determine any given set of test results. On the other hand, the method of "normalizing errors" used in industrial measurements does not satisfy the conditions of bench tests of hydraulic machines, since it does not provide sufficiently accurate estimates of errors. The method of "normalizing errors" consists in specifying relative tolerances (the degree of accuracy) over a wide range of measurements.

The error of indirect test results is determined in this case from a formula, which is obtained by substituting the differential of the function characterizing the relation between the indirect and final results by its equivalent increment. Thus, when specifications for testing hydraulic machines [1, 2] were developed, it was found necessary to specify measuring instruments and even methods of connecting them and the conditions of their use instead of specifying the accuracy of measurements.

The problems being solved in bench testing of hydraulic machines require reliable means of determining errors of testing. It should be noted that, for certain bench measurements, it is possible to obtain statistical parameters of accuracy, for instance the root-mean-square error. In this connection, considerable practical interest is attached to methods whose application to final results, based on measurements which, either in part or completely, were not repeated several times, still provides a parameter of accuracy similar to the rms error. If it is possible to add such a parameter (according to the law of adding mean errors) to statistical parameters for obtaining a sufficiently accurate idea of the precision of the indirect measurement, the above problem becomes solved.

Such methods are known and used for determining the measurement error of the flow of liquids by means of normal constricting devices.

One of these methods, described in rules 27-54 [3], makes it possible to apply the law of adding errors in the case of single indirect measurements, providing it is possible to evaluate the maximum error of the final measurements. The reliability of this method is lower than that of the statistical determination of accuracy, but completely satisfactory for the majority of bench testing instruments for hydraulic machines.

Another method described in the proposed international standard for measuring the flow of liquids [4] makes it possible to determine the error of a single indirect measurement more accurately than the first method here described, owing to the presentation of the errors of final measurements as the sum of a series of independent values which characterize the conditions and methods of carrying out the final measurements. This

method is more complicated than the first one and requires a greater expenditure of effort. Its use is therefore advisable only when final measurements are made with great precision, and the accuracy of the indirect measurement is reliable.

We consider it possible to use by way of the first approximation the method described in regulations 27-54 in the case of the majority of indirect measurements carried out in testing hydraulic machines, thus laying the foundations for a general method for evaluating the accuracy of bench measurements.

According to regulations 27-54 the rms relative error ($\dot{\sigma}$) is taken as the parameter of the accuracy of measurements. The basic values involved in determining the results of indirect measurements of the flow of liquids by the pressure difference in the existing device are divided into two categories.

The first category includes quantities whose rms errors are determined by statistical treatment of repeated measurements of these values under conditions similar to those involved in the given indirect measurement (the flow factor and a correction for the expansion of the medium under test). The second category includes quantities whose rms errors are unknown, but whose maximum possible errors are known (diameter of the pipe, pressure, temperature, pressure difference, etc., as well as several values which are determined from reference tables).

In the case of the second category quantities, the maximum possible error is equated to a statistical parameter, the maximum error (3σ). This is justified by the fact that, according to the law of random error distributions (for a sufficiently large number of measurements) for every 370 errors there is only one equal to 3σ. It is possible to assume with sufficient certainty that the maximum possible error occurs with a similar frequency. Then one-third of that error can be added (according to the law of adding mean errors) to the rms errors of other final measurements.

The error thus obtained for the indirect measurement does not possess the full certainty of an rms error, which is obtained in adding the actual mean errors when they are known. This should be taken into account, especially since the degree of approximation to the actual rms errors of indirect measurements in the above method depends to a great extent on the method of determining the maximum possible errors in measurements whose rms errors are known, and on the fraction of the total error due to indirect measurements, which is made up by the sum of the squares of the accuracy parameters found by the above method. According to regulations 27-54, the maximum possible error of single measurements is taken to be equal to the permissible basic error of the instrument used for measurements. For the majority of instruments, this error is expressed in the percentage of the total measuring range, and is numerically equal to the grade of the instrument.

The maximum error of the quantities taken from the tables is assumed to be equal to half the value of the last significant figure.

It is possible to expect that the above method of determining the indirect measurements error will find wide application in hydraulic machine testing owing to its simplicity and uniformity. It is important to note that the reliability of the results thus obtained can be greatly increased if special investigation is made of the measuring instruments under their normal operating conditions on the bench and the actual values of their mean errors determined for these conditions.

In order to compare the results obtained by means of this technique and that of "normalized errors", let us examine the most common indirect measurements of efficiency in testing hydraulic machines. The required efficiency is obtained from the final measurements of the capacity Q of the pump, the head H, the specific gravity γ of the liquid used, the torque M at the pump axle and the motor speed $\underline{n}$ from the formula

$$\eta = K\frac{QH\gamma}{Mn}, \tag{1}$$

where K is a coefficient depending on the dimensions of the quantities used in the formula.

The capacity of the pump is normally determined by standard diaphragms. The root-mean-square relative error of measuring capacity σ_{0Q}, according to the regulations 27-54, amounts for medium-capacity pumps to approximately 0.7%.

The head is determined as the difference of the readings of two reference grade 0.3 manometers, and experience has shown that on the bench their rms error is approximately equal to the tolerance (the grade of accuracy) instead of a third of its value. Hence, $\sigma_{OH} = 0.6\%$.

The torque at the pump axle is usually measured by means of a balancing motor (motor scales) and σ_{0M} can be easily determined (for the conditions of bench operation) by means of repeated measurements at various speeds and loads on the drive of the motor-scales stator. These tests almost exactly reproduce the conditions of measuring torque by means of motor scales when pumps are being bench-tested. The value of σ_{0M} for medium-capacity motor scales with dry frictionless bearings on the stator amounts to 0.2%.

The speed of revolutions is measured by means of a SK751 grade 1 tachometer, i.e., the value of the error may be taken as $\sigma_{0n} = 0.33\%$.

The errors $\underline{k}$ and σ can be neglected, since their values can be made sufficiently small.

Then the rms relative error of measurement of efficiency $\sigma_{0\eta}$, determined from formula

$$\sigma_{0\eta} = \sqrt{\sigma_{0Q}^2 + \sigma_{0H}^2 + \sigma_{0M}^2 + \sigma_{0n}^2}, \tag{2}$$

amounts to 1% and the limiting error $3\sigma_{0\eta}$ is 3%.

The evaluation of the accuracy of efficiency measurements on the bench by the dispersion of experimental points, when the characteristic is converted by means of similarity formulas, shows that the rms error determined from regulations 27-54 usually characterizes well the accuracy of measurements; whereas the "normalization of errors" method produces excessive values (in this case, 4%).

A reliable method for determining the measurement accuracy is essential not only for investigating hydraulic machines. New machines are often accepted by the industry on the basis of their improved working characteristics. The comparison of characteristics requires the knowledge of their possible errors. This is particularly important when mass-produced or high-power machines are put on the market.

Metrological institutes should develop and introduce efficient techniques for determining accuracy of measurement parameters. We think it will be possible to use for this purpose the convenient and practical method of evaluating the accuracy of indirect measurements by the method suggested in regulations 27-54.

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OPTICAL MEASUREMENTS

A RATIO-MEASURING PHOTOMETER

I. G. Gol'dreer and M. L. Petrova
Translated from Izmeritel'naya Tekhnika, No. 5, pp. 57-59, May, 1960

The use of the logometric method (i.e., the method of measuring ratios) in designing photoelectric measuring equipment makes it possible to avoid the greater part of the defects which are inherent in direct-reading photoelectric instruments and in instruments based on measuring or balancing the difference of the two fluxes being compared.

The strict application of the logometric principle presupposes the existence of a) a common source of light which determines the luminous flux of both the objects being compared (obviously excepting the case when the objects being compared consist of two light sources); b) a common transducer; c) a single-channel amplifier in the electronic measuring circuit, i.e., a strictly single-channel operation both in the optical and electronic circuits of the equipment.

The fulfillment of these conditions provides a complete elimination of the effect of possible instabilities of the parameters or conditions of operation of the light source, light-sensitive elements and electronic circuit components on the measurement results. The application of the logometric method thus makes it possible to develop instruments which provide considerable stability and good reproducibility of measurements.

The method discussed in this article can be used for constructing photometers which facilitate the solving of various spectroanalytical problems. The same electronic measuring device can be used in practice for the solution of all such problems. The pecularities of any particular optical measurement are taken into consideration when the corresponding opticomechanical device is being designed to serve as a transducer for the electronic circuit.

The two luminous fluxes which are to be measured are first modulated by means of some modulating device with two frequencies f_1 and f_2 which are not in a harmonic relation to each other (Fig. 1). After modulation both luminous fluxes are fed to the cathode of a photomultiplier (or photocell), thus producing at the photomultiplier output a complex electrical signal, which consists of the sum of two oscillatory processes approaching a sinusoidal shape. Providing the value of the measured luminous fluxes does not exceed the linear portion of the photomultiplier light characteristic, the relation of the amplitudes of these oscillations will be determined only by the ratio of the luminous fluxes and will be independent of the sensitivity, fatigue or supply voltage of the photomultipliers.

The electronic circuit amplifies the total signal linearly without changing the ratio of the amplitudes. The division of the signal into components, i.e., separation of the two sinusoidal signals, is made by means of a simple selective amplifier. The selective amplifier consists of an electron tube which has two circuits in its anode tuned to the modulation frequencies f_1 and f_2. The signal of frequency f_2 is fed from the amplifier straight to the measuring instrument. The signal of frequency f_1 is fed to the so-called subtracting stage. This stage is also fed with a reference blocking voltage from any stable source (for instance, a stabilivolt). The amplified difference of the voltages $U = U_{f_1} - U_{stab}$ is used as a controlling voltage in the negative feedback. The object of the feedback is to keep constant the voltage of frequency f_1 at the output of the tuned amplifier by changing the gain of the amplifying circuit. Any increase in the amplitude of U_{f_1} at the output of the tuned amplifier leads to a rise in the feedback voltage and automatically returns U_{f_1} to its original value. A reduction in the value of U_{f_1} leads to a decrease in the feedback, i.e., to a rise in the gain which again brings U_{f_1} back to its original value. A

change in the gain for the signal of frequency f_1 leads at the same time to a similar change in the gain for the signal of frequency f_2, since the circuit is the same for both frequencies.

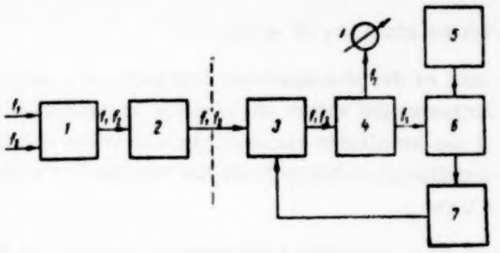

Fig. 1. Block schematic of the logometric photometer. 1) Photomultiplier; 2) preamplifier; 3) adjustable potential divider unit; 4) selective amplifier; 5) source of the reference voltage; 6) the subtracting stage; 7) feedback power amplifier.

If the value of the two compared luminous fluxes is determined by a single light source and the law of the variation of these fluxes with changes in the source is the same, the ratio of the amplitudes of the electrical signals $K = U_{f2}/U_{f1}$ at the output of the selective amplifier is determined only by the individual properties of the two optical objects being compared. If, however, the source of the signal frequency f_2 consists of a stable object, the entire work of the circuit is reduced to the measurement of the ratio K which has as its denominator a constant quantity, i.e., to stabilizing the measuring conditions of signal U_{f2}. The indicating instrument which measures the value of U_{f2} in relative units, is, in fact, measuring the ratio K which has a constant denominator.

The accuracy of such a logometric device is determined by the stability of the reference voltage U_{stab} and the value of the feedback gain.

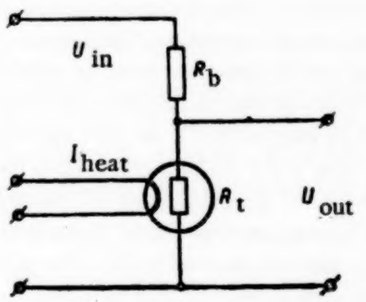

Fig. 2. Controlled potential divider

In the model of the instrument developed by us, a stabilivolt is used as a source of the U_{stab} voltage supply. The controlled elements of the electronic circuit consist of two potential dividers made up of two thermistors with indirect heating and ballast resistors (Fig. 2). A rise in the heating current I_{heat} leads to a decrease in the thermistor resistance and, hence, to a drop in U_{out} of the controlled divider. The simultaneous reaction of the feedback on the two controlled elements increases the efficiency of the control. The use of two controlling elements provides a sufficient accuracy in measuring the ratios when the absolute levels of input signals are changed by a factor of 15-20.

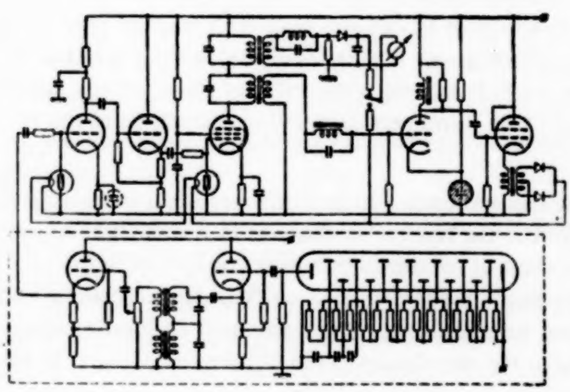

Fig. 3

Figure 3 shows the electronic circuit diagram of this device.

It has already been pointed out that, on the basis of the above method, photometers can be designed for the solution of various spectroanalytical problems (absorption, fluorescence measurements, flame photometry, etc). Their development is reduced to finding concrete transducers for various cases. The transducer must contain an illuminator and an optical system corresponding to the required method of analysis, a modulating device and a light-sensitive element with an output unit. In designing the transducers, the following fundamental requirements must be observed:

1. It is necessary to ensure a strictly defined position for the objects of testing, i.e., a complete reproducibility of the conditions of illumination of the objects and the photocathode by the light source.

2. The optical properties of the substance selected as the "standard" must bear the same relation to the variations in the source of light as the similar properties of the object under test. The substance used as a "standard" must be stable with time. Its temperature coefficient must correspond to that of the measured object.*

3. The modulating frequencies f_1 and f_2 must be stable with an accuracy of $\leq 1\%$.

4. Both luminous fluxes must be projected onto the same spot of the photocathode and produce a uniform illumination of the whole working surface. This requirement eliminates the effect of possible variations in the sensitivity of various portions of the photocathode on the value of the amplitude ratios of the electrical oscillations at the output of the photomultiplier; i.e., it provides a measurement of the ratio of the two luminous fluxes independent of the stability of the photocathode parameters with time.

As an example of the application of this logometric method, let us examine a logometric photometer FF-2 intended for luminescent analysis of semitransparent beads of NaF(U) for admixtures of uranium.

Instrument FF-2 consists of two separate units, a transducer and an electronic measuring unit.

The transducer contains an opticomechanical portion, a photomultiplier, a preamplifier and a connection to the electronic unit by means of two cables, one of which transmits the high voltage to the photomultiplier, and the other supplies the anode and heater voltages to the preamplifier, the voltage for the motor, and the ultraviolet source of light, and connects the output of the preamplifier, to the electronic unit. The optical circuit of the FF-2 photometer is shown in Fig. 4.

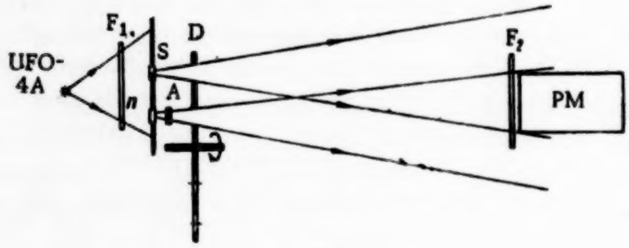

Fig. 4

The light from lamp UFO-4A passes through filter UFS-3 (F_1) which passes the ultraviolet radiations to the "standard" S and the analyzed bead n, making them luminescent. The standard consists of a glass ZhS-9 plate whose maximum luminescence coincides with that of the luminescent bead of NaF(U). The luminous fluxes of the "standard" and the bead are modulated by frequencies $f_1 = 1200$ cps and $f_2 = 2650$ cps. The filter ZhZS-9 (F_2) admits the luminescent radiations to the cathode of the photomultiplier after they have been transmitted through disk modulator D which has two rows of holes. The photomultiplier is placed in such a position that its cathode is fully illuminated by both the fluxes under comparison. The instrument employs an optical method of switching the ranges. This "switch" consists of a holder carrying neutral light filters A (attenuator) of varying optical densities. The placing of a neutral filter in the path of radiation of the bead provides variations in the ratio U_{f_2}/U_{f_1} in steps of known integers. The control knob of the holder with indications of the range number is mounted on the side wall of the instrument. The ranges are switched by hand. Readings of U_{f_2}/U_{f_1} are read off a pointer instrument, mounted on the front panel of the electronic unit. The same instrument is used for checking the operation of the entire set. In a certain position of the special tumbler switch, it measures the value of the feedback, which determines the operating condition of the measuring device. The instrument is supplied directly from the ac mains.

Owing to the use of the selective amplifier, the instrument possesses a high sensitivity when measuring weak luminous fluxes. The instrument makes it possible to determine the content of uranium in a NaF(U) bead weighing 5 mg in the range of $5 \cdot 10^{-11}$ to $1 \cdot 10^{-6}$ g/bead. The error of measurements does not exceed 2-3% with mains variations of ±10% and ambient temperature changes in the range of +10 - +40°C. After continuous operation for 8 hours, the instrument does not require recalibration or correction. The instrument calibration does not vary when tubes are changed. Ya. V. Puminov participated in the development and adjustment of some of the elements of the circuit.

* In applying the above method to spectral analysis, it is possible to use as a "standard" any line homologous to to the one being analyzed.

ESSAYS AND REVIEWS

PHOTOCOMPENSATED RECORDING SERVO SYSTEMS

A. M. Ilyukovich

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 59-60, May, 1960

Photocompensated servo systems recording attachments to instruments are now being used for various measurements.

The principle of operation of these attachments consists of the following. A beam of light reflected from the mirror, which is fixed to the axis of the moving part of the measuring device, falls on a photovaristor mounted on the recorder carriage. A pen or another recording device is also fixed to that carriage for recording the position of the carriage on a chart which moves at a constant speed. The carriage is driven by an auxiliary motor. When the beam of light is deflected, the motor is switched in and returns the carriage to a position of maximum illumination of the photovaristor. Thus, the carriage of the recorder follows the direction of the beam, i.e., it follows the displacements of the moving part of the measuring mechanism. Moreover, this operation does not produce any additional mechanical loading on the measuring mechanism, thus making its operation accurate.

An instrument of this type [1] is made by the firm Elektronest, Ottenhausen-Saarbrücken(FGR) under the name of "photodyne". It consists of a recording attachment for any type of instrument using a deflecting mirror. The attachment is supplied with a light filter for protecting the photovaristor from interference by extraneous sources of light and with a lens used for focusing the beam onto the photovaristor.

The maximum speed of the carriage is 600 mm/sec, and the maximum acceleration, 4 m/sec^2.

The attachment can be used with instruments whose moving part has a natural oscillation period of not less than 1 sec.

The technical characteristics of the attachment are the following: width of recording 210 mm; recording error ± 0.2 mm; distance between the instrument and the attachment up to 3 m when the instrument uses a 3 × 10 mm mirror; minimum distance between them is 1.5 m when a 3 × 3 mm mirror is used and illuminated by a 5 w lamp; the speed of the chart movement is 1.2 - 3 - 6 - 12 - 30 - 60 - 120 - 300 mm/min; the linearity of the attachment is 0.2%; it is fed from a 50 cps 110-125-145-220-245 v supply; its consumption is about 100 w; its over-all dimensions are 380 × 300 × 420 mm, and its weight 19.5 kg.

Another photocompensated recording instrument [2] under the name of "nanograph" is made by the firm Celfram (France).

The instrument consists of two galvanometers and a recording attachment. Each galvanometer is used either as a current or voltage measuring device.

The first galvanometer (type SV4SD) has one galvanometer current range (about 1 μa with an internal resistance of 20 ohms) and 5 measuring ranges of 2 - 5 - 10 - 20 - 50 μa. The voltage drop across the galvanometer winding is 1 mv. The voltage measuring ranges of this galvanometer are 0.2 - 0.5 - 1 - 2 - 5 - 10 mv for an operating current of 1 μa.

The second galvanometer (type SV1CD) has a galvanometer range of about 0.2 μa with an internal resistance of 670 ohms and measuring ranges of 0.5 - 1 - 2 - 5 - 10 μa with a voltage drop of 5 mv. The voltage measuring ranges are 5 - 10 - 20 - 50 - 100 - 200 mv at a current of 0.2 μa.

The technical characteristics of the instrument are: the width of the recording chart of each galvanometer is 112 mm; the natural oscillation period of each galvanometer is 1.8 sec; the consumption of the instrument is about 20 w; it is fed from a 50 cps 110 - 127 - 220 - 240 v supply; its over-all dimensions are 480 × 290 × 200 mm,and its weight is 18 kg.

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2. Enregisteur "Nanograph" à 2 voies, Mesures et controle industr. 24, 269 (1959).

INFORMATION

FRENCH MEASURES EXHIBITION

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 60-61, May, 1960

The French Measures Exhibition, which was opened on March 22 in Moscow,* completed its work on April 3, 1960.

In the five halls occupied by the exhibition, many different measuring instruments and apparatus were exhibited, which represented the latest achievements of the French instrument-making industry in the sphere of electrical, radiotechnical, electronic, nuclear and optical measuring instruments, automatic control and monitoring devices, as well as radio and television sets. At the same time, in a specially equipped hall, the leading French specialists of instrument-making firms read lectures on various subjects in the sphere of measurement technology. The lectures were illustrated by slides and films.

A large stand with books, monographs and periodicals issued in France on measurements in various branches of science and technology was placed at the entrance to the exhibition. The attention of the visitors to the exhibition was mainly directed to the electrical, electronic and radiotechnical instruments.

Among the numerous electrical measuring instruments, we shall note the most original ones.

Microampere-voltmeter with a light beam projection type T-223 of the firm AOIP has twelve ranges with an over-all coverage of 7.5 to 150 μa and 0.5 to 150 mv, a free oscillation period of 2 sec and a winding of 20 ohms. The instrument's moving part is fixed on torsion suspensions and is hardly affected by the position of the instrument.

A miniature electronic recording potentiometer type PE-2500 made by the same firm. The peculiarities of this instrument include a fully transistorized amplifier. The instrument has 6 ranges, with an over-all measuring range of 2.5 to 1000 mv; its measurement error is 0.5% of the full-scale reading, its input resistance is $4 \cdot 10^5$ ohms/v; it records by means of ink on a chart 100 mm wide in rectangular coordinates; the time taken by the pointer to traverse the whole scale is 0.5 sec. The speed of the chart movement ranges from 15 mm/min to 240 mm/hr. Its external dimensions are 144 × 144 × 540 mm, and its weight is 15 kg.

A dc voltmeter with a dynamic capacitor type AS of the firm SAIP. The voltmeter has an input resistance of 10^{15} ohms, and it has 5 ranges with a coverage of 30 mv to 3 v and a drift not exceeding 1 mv in 24 hours. The instrument is supplied from ac mains.

This firm exhibited many instruments for radioisotopic investigations. The instruments use decatrons and trochotrons in a circuit consisting of separate units. These instruments include a 60-channel pulse amplitude analyzer type SA60M with a magnetic memory. The channel width is controlled within the limits of 0.1-1 v with an error of ± 1%; the resolution of the instrument amounts to 500 μsec. The capacity of each channel is 65,535 pulses.

The Lemouzy Company exhibited a dc voltmeter with an output resistance of 10^{14} ohms, which covers a measuring range from a few mv to several kv and microammeters with an input resistance approaching zero and providing dc current measurements between 10^{-3} and 10^{-14} amp.

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* See Izmeritel'naya Tekh. 2 (1960) [see English translation].

Many digital indicating instruments were exhibited by the firm Rochar Électronique.

A digital voltmeter type A-902 with 3 indicator points on an illuminated plate measures dc voltages up to 100 v with an error of ±0.1%; the measuring time amounts to 1 sec. The instrument has also outputs for connection to various registering devices and calculating machines. Its external dimensions are 510 × 230 × 320 mm; its weight is 13 kg.

Various digital frequency meters, instruments for measuring periods and intervals of time, made by the same firm, are also of considerable interest. For instance, instrument type A-479, which counts pulses at a frequency of 1.2 Mc and has a counting capacity of 9,999,999 pulses. When operating as a frequency meter, the instrument has an input resistance of 1 meg and operates with an effective input voltage from 20 mv to 50 v. Its external dimensions are 545 × 395 × 485 mm, and its weight is 41 kg. When operating in conjunction with a heterodyne converter A-729, this instrument measures frequencies up to 220 Mc.

This firm has also exhibited various electronic flowmeters, tachometers, chronographs, ultrasonic instruments for fault location, uhf instruments and devices for automatic control and monitoring.

The Anter Company exhibited a 60-tube recording potentiometer "titromatique carré" for recording physicochemical processes. The instrument provides automatic titration, photometry, chromatography, and electrophoresis of liquid media. The recording with respect to two coordinates is made on a 200 × 250 mm chart in different colors. The over-all dimensions of the instrument are 810 × 475 × 490 mm, and its weight is 53 kg.

The LEA instrument for ultrasonic nondestructive investigation of the strength of materials and constructions has an original design. Side by side with various transducers and receivers of ultrasonic vibrations, this firm also exhibited an automatic harmonic analyzer type AF-10 s/h for frequencies from 10 to 50,000 cps. The instrument incorporates a tuned amplifier with electromechanical tuning which provides a scanning of the whole range in 15-150 sec; the measurement error of harmonic amplitudes is ±2%; the bandwidth of the instrument is 3-30 cps.

The same firm also exhibited a quality meter type END-20 which measures the nonlinear distortion coefficient of electrical voltage signals of 50 mv to 225 v at 20 to 25,000 cps in the range of 0.1 to 100%.

A universal electrical measuring instrument "precitest" made by Chauvin-Arnoux is of interest; it is intended for measuring dc and ac currents and voltages as well as resistance in 22 ranges; it has a triple overload protection, and is shock-, concussion- and vibration-proof.

A large number of instruments for physicotechnical investigations and production control of liquid and gaseous materials were also shown at the exhibition. Among them should be noted the electronic spectrometer, made by Jobin et Yvon, and intended for automatic analysis of absorption spectra in the range of 2000-12,500 A, or fluorescent, monochromatic diffusion, and other spectra of various sources. The instrument is supplied with a large number of auxiliary devices which considerably extend its sphere of application. The same firm has shown a chromatograph type Bretagne for analyzing liquid and gaseous mixtures. The instrument is equipped with a recording electronic potentiometer having a 250 mm chart. The error in analyzing various mixture components does not exceed 1-7%. In 30 min the instrument can record the results of the analysis of 120 components.

The spectrograph of the Cameca company is intended for a qualitative analysis of metal alloys with an error not exceeding 0.3%, with a time spent on analyzing each component amounting to 7-12 sec.

The diverse laboratory equipment exhibited by the firm Jouan included a spectrometer "nuclear spectrograph" for working with radioactive materials and completely automatic, with recording in the range of 1850-11,000 A; pH-meters of the "professional" type with a sensitivity of 0.05 pH and "Carpeni-constant" meters with a sensitivity of 0.01 pH.

Optical instruments, although in smaller numbers, were also exhibited. They included a projection dioptrimeter of the front-photometer type made by the Societé de Lunetières. This instrument is intended for measuring deviations (± 0.02 diopters) from the normal, for spherical, astigmatic and prismatic spectacle glasses. The firm Précision Méchanique Labinal exhibited a single objective instrument type ALCA for measuring surface roughness calibrated in 0.1 μ.

The firm OPL exhibited a universal electron microscope with a continuously controlled magnification from 1500 to 100,000 and a resolution of 25 A. The same firm showed an interesting optical micrometer type 54 which

can be easily attached to any metal-cutting machine. This small instrument has a magnification of 10, and is calibrated in 0.01 mm with an error of about 2μ. The reading is taken from three images of parts of the scale projected onto a frosted glass.

The various instruments for linear measurements under production conditions were shown by the Manurhin company, including gauge blocks, used in engineering and made in the shape of a figure eight easily assembled on two special pins. The same firm exhibited a miniature measuring head "Manudelta" for checking lengths of details in production, which makes it possible to control tolerances of linear dimensions between 1 and 1000μ. The firm also showed an adjustable dial snap-gauge for threaded articles 4 to 60 mm in diameter with a pitch of 0.5 to 3 mm and capable of making up to 600 measurements per hour.

The firm CGR exhibited several instruments for measuring vacuum: amplivac-20, an ionization instrument for measuring pressures of $5 \cdot 10^{-7}$ to $1 \cdot 10^{-3}$ mm Hg; thermivac-11, an instrument using thermistors for measuring pressures from 10^{-2} to 20 mm Hg; ionivac-31, an instrument with an ionization chamber in a magnetic field for measuring pressures of $1 \cdot 10^{-6}$ to $1 \cdot 10^{-2}$ mm Hg.

In a separate hall, transmitting and receiving television equipment was demonstrated, as well as miniature precision elements and components (resistors, capacitors, potentiometers, etc.), for radiotechnicial and measuring instruments.

BOOK REVIEWS

THE TECHNIQUE OF MEASURING DENSITY OF LIQUID AND SOLID BODIES

S. S. Kivilis
Standartgiz, Moscow, 1959, 189 pages, 73 illustrations
Translated from Izmeritel'naya Tekhnika, No. 5, pp. 62-63, May, 1960

The recently published book, The Technique of Measuring the Density of Liquid and Solid Bodies, is very topical. Since the publication in 1949 of the instructions on the technique of measuring density,* this is the first book which provides a systematic description of the foundations of the theory and practice in measuring the density of liquid and solid bodies.

A vast experience has been accumulated in recent years in the sphere of measurement techniques in the instrument-making industry; new methods have been rapidly developed for measuring density, especially methods of industrial control connected with production automation; automatically operating instruments and density regulators are being used in practice, and continuous control by means of remote control methods is being applied.

In the area of metrology and inspection, better methods have been developed for checking and inspection, new instructions, standards and tables issued and old ones amended.

It is only natural, therefore, that old textbooks dealing with the technique of measuring density have become out-of-date and require replacement by new ones which reflect the modern technique in this sphere.

There is no doubt that the book under consideration is of great interest. The author has spent much effort in order to collect the newly accumulated material, systematize it, and take into consideration the latest developments in the sphere of density measurements.

The author of the book has dealt with several questions in a creative manner, having given the theoretical material a more systematic character; he analyzes in detail the very important question of units for measuring density and of unit systems in general, and he describes a technique for practical measurements, with inclusion of many instructions on inspection of instruments.

A large part of the book is devoted to alcoholometry and the measurement of density of oil products. The very important questions dealing with the most up-to-date instruments and automatic machines for a continuous measurement of density are also discussed. The book consists of six independent chapters. Chapter I deals with basic concepts and definitions, measuring units and systems, the relation of density to temperature, pressure, etc.

In this chapter density and specific gravity are rigorously defined, eliminating any possible difference in interpretation or confusion of these concepts, which still occur occasionally in literature, especially with respect to specific gravity and relative density.

The author compiled tables of considerable importance from the practical point of view for converting one type of density unit to another, and tables of factors for correcting density values in case of conversion to other units.

The same chapter deals with problems of bulk expansion of liquids due to temperature; it provides methods for compiling temperature correction tables and deals with problems connected with the evaluation of the quality and quantity of water-alcohol solutions, indicating the method of compiling tables of instrument readings and tables for a qualitative evaluation of alcohol.

* I. K. Turubiner, M. D. Ippits. Technique of Density Measurements (Mashgiz, 1949).

The author should in future clarify certain problems, explaining for instance, why, in the example quoted on page 14, the coefficient $\underline{a}$ in formula (8) depends on the normal gravitational acceleration. This fact may be confusing to a reader who has not a clear understanding of the systems of units. There is also an unfortunate misprint in the conversion formula on page 7, where the quantity is given in kg/cm^3 instead of kg/m^3.

Chapter II deals with the foundations of areometry and is treated most fully by the author, including many tables and indications of the technique to be adopted in practical work. This chapter includes the description and the principles of operation of areometers according to their intended application and their accuracy, and deals with the theory and design of areometers. The foundations of the theory of capillary phenomena and their effect on the areometer readings are adequately dealt with, including the method of determining surface tension in liquids and calculation of the capillary effect. The description is accompanied by the required tables, illustrations and examples.

Unfortunately, the author does not pay sufficient attention to certain peculiarities of surface phenomena, or to the differences in the readings of areometers caused by them, as well as to the methods of eliminating these errors.

A detailed examination is made of the effect of temperature on the areometer readings and of the method of calculating corrections. Recommendations on the use of areometers and instructions on the checking of areometers and the equipment of inspection laboratories, etc., are also given.

Chapter III deals in sufficient detail with the theory and design of metal alcoholometers, the manner of compiling tables for them, and the technique for using the instruments and the tables. Methods for checking these instruments are indicated, as well as the equipment required for this purpose.

In chapters IV and V the weighing method of determining density is described, including hydrostatic weighing and the pycnometric methods. A detailed description and theoretical analysis of these methods is supplied, their peculiarities are noted, and the required formulas quoted. The author gives several practical suggestions for determining the density of liquid and solid bodies by means of these methods, and on the use of instruments and equipment. The description, theory, design and checking of hydrostatic scales is dealt with separately.

The book does not mention, however, the significance of these methods in calibrating areometers. In these chapters one comes across other inaccuracies: for instance, it is not stated that in determining the volume of the float by weighing it in water, the expansion coefficient of the glass it is made of should be known. That is why floats are normally made of thermometric glass whose expansion coefficient is known. On page 118, in the penultimate paragraph, it is not explained that during hydrostatic weighing on commercial scales, it is possible to ensure a better thermostatic control of the liquid.

S. S. Kivilis, for the first time, introduces in a book on technical measurements of density a description of the industrial methods of controlling the density of liquids. To date, the books only dealt with laboratory methods of measurement. At the present time, however, the laboratory methods of measuring density hinder industrial control and cannot be used in conveyor systems. Therefore, continuous measurements of density directly in the flow of liquids are now being used in industry, and density gauges which measure various constants indirectly related to density are also being used.

We have not as yet a set of such instruments; the mass production of density gauges is small, the majority of instruments are in the development stage. Moreover, they are often developed by the plants themselves to meet their particular requirements, and therefore, each type of instrument has many varieties determined by the differing production methods.

It is naturally impossible to examine all these instruments; it is only possible to note representative instruments for each type and the common principle of operations for each type. Nevertheless, the author has successfully analyzed the vast body of information derived from both our own and foreign measuring equipment industries, and has found it possible to cite many different types of instruments and their variations.

The book provides a clear classification of the types of these instruments on the basis of the principle of their design and thoroughly examines a representative instrument of each type.

The author examines five types of instruments and density regulators: of the float type, weighing type, the hydrostatic (piezoelectric), radioactive and (in part) ultrasonic types. Schematics of these density gauges and their varieties are provided.

It is, of course, impossible to provide an exhaustive metrological characteristic of these instruments or rules for their use, since in each particular case these problems have to be solved in a particular manner. However, methods of calibrating the scales of some of the density gauges should be indicated or a general basis for their calculation provided in order to make this chapter not only descriptively, but also practically, useful.

It should be noted that in describing the density gauges the author often refers to other instruments, which may not be known to the reader. A brief description of these instruments should have been given, or it should have been indicated where further information on these instruments is obtainable.

A description of conductometric instruments is not included in the book, despite the fact that they are being widely used in industry. Although these instruments have a rather special character (like the optical methods of measurement, which are also omitted), and their readings are greatly affected by the properties of the measured liquid, it would have been advisable to have indicated the principle of their operation, drawing the reader's attention to their peculiarities: their high sensitivity, lack of a single reading, etc.

All the existing defects, however, do not detract from the value of the book.

The book was printed in relatively small numbers (3000 copies), and it should be reissued.

M. D. Ippits

COMMITTEE OF STANDARDS, MEASURES, AND MEASURING INSTRUMENTS

I. NEW SPECIFICATIONS FOR MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE

NEW STANDARDS REGISTERED IN MARCH-APRIL, 1960

GOST 7590-60. Frequency meters. Technical requirements. Replacing GOST 7590-55.

GOST 8039-60. Phase meters. Technical requirements. Replacing GOST 8039-56.

GOST 8476-60. Wattmeters and VAR-meters. Technical requirements. Replacing GOST 8476-57.

GOST 9409-60. General-purpose dynamometers. Types and basic parameters. First issue.

GOST 9411-60. Optical colored glass. First issue.

II. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE AS THE RESULT OF STATE TESTS AND PASSED FOR USE IN THE USSR

REGISTERED IN APRIL, 1960

High-frequency instrument current transformers, trade mark I509, of the Kiev Sovnarkhoz. State Register No. 1318-60.

Equipment for checking current transformers at high frequencies, trade mark U5014, of the Kiev Sovnarkhoz. State Register No. 1319-60.

Lever type resistance boxes, trade mark R32, of the Krasnodar Sovnarkhoz. State Register No. 1320-60.

Lever type resistance box, trade mark R33, of the Krasnodar Sovnarkhoz. State Register No. 1321-60.

High-resistance dc potentiometers, trade mark R300, of the Krasnodar Sovnarkhoz. State Register No. 1322-60.

Low-resistance dc potentiometers, trade mark R306, of the Krasnodar Sovnarkhoz. State Register No. 1323-60.

High-resistance dc potentiometers, trade mark R307, of the Krasnodar Sovnarkhoz. State Register No. 1324-60.

Thermal power-comparators, trade mark T119, with a P119 power supply, of the Leningrad Sovnarkhoz. State Register No. 1325-60.

Checking equipment for dc and ac purposes, trade mark U1133, of the Krasnodar Sovnarkhoz. State Register No. 1326-60.

Rack mounted wattmeters for checking electric boring machines, trade mark D-318, of the Krasnodar Sovnarkhoz. State Register No. 1327-60.

Portable kilovoltmeter, trade mark S-100, of the Leningrad Sovnarkhoz. State Register No. 1329-60.

III. MEASURES AND MEASURING INSTRUMENTS EXCLUDED FROM THE STATE REGISTER

Lever resistance box RMS-1. State Register No. 102.

Rack mounted ammeters M415. State Register No. 117.

Rack mounted voltmeters M415. State Register No. 118.

Resistance box. MS-38. State Register No. 180.

Megohmmeter MMG-1. State Register No. 205.

Lever indicator IR. State Register No. 111.

Resistance box KDS. State Register No. 204.

High-resistance potentiometers PPTV-1. State Register No. 663.

Megohmmeter MOM-5. State Register No. 235.

Rack mounted ammeters. É113/1. State register No. 377.

Rack mounted voltmeters É112/1. State Register No. 378.

Rack mounted ammeters M210. State Register No. 396.

Rack mounted voltmeters M210. State Register No. 397.

From July 1, 1960:

DC bridge MTV. State Register No. 774.

Low-resistance DC potentiometers PPTN-1. State Register No. 785.

Line Wheatstone bridge MVL-47. State Register No. 412.

Rack mounted ammeters M213. State Register No. 414.

Rack mounted voltmeters M213. State Register No. 415.

Detector type frequency meter DCh-49. State Register No. 705.

Recording portable ammeters and voltmeters M323 and M323/1. State Register No. 777.

Portable ohmmeters M313. State Register No. 807.

Urine hydrometers. State register No. 829.

DC potentiometers R375. State Register No. 1137-57.